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Plastics

DEALING WITH THE MANUFACTURE, USES AND POTENTIALITIES OF PLASTIC MATERIALS

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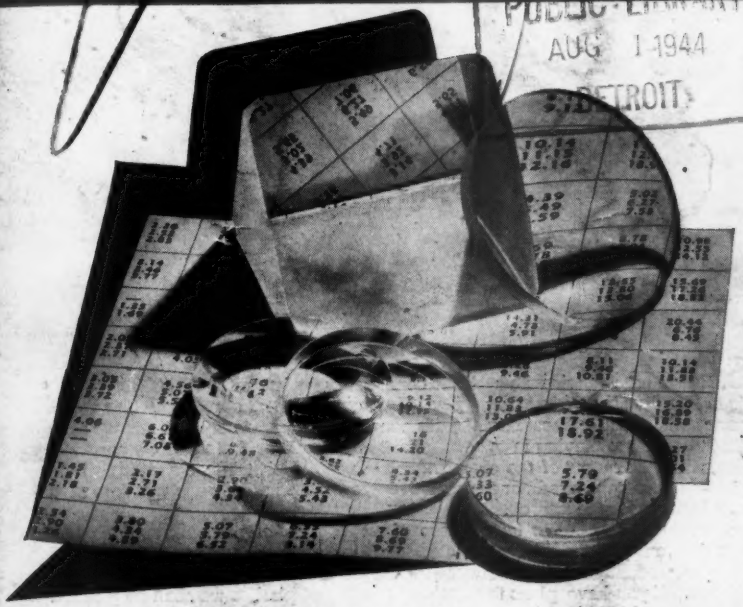

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Two types of plastics are produced by I.C.I. in a special quality for optical work. They are unplasticised polymethyl methacrylate (known as "Transpex" 1), which is equivalent to optical Crown Glass, and unplasticised polystyrene (known as "Transpex" 2), equivalent to optical Flint Glass. The materials are being used extensively in the construction of optical equipment such as cameras, binoculars, spectacles and projector systems. "Transpex" 1 and "Transpex" 2 materials are available in a variety of thicknesses and sizes in sheet or block form. Full information concerning them and the many other I.C.I. plastic products will be sent on request.

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SHE puts up her hair with a plastic comb; surveys herself in a plastic mirror; a plastic bracelet on her wrist; bright plastic buttons ornament her dress. She is one of a generation rapidly becoming plastics conscious. She has at least heard of the part that plastics are playing in the war-effort. She realises that war-time demands have curtailed the output of the charming plastic novelties, trinkets and household devices that once captivated her appreciative eye, and sometimes she wonders what we have in store for the future . . .

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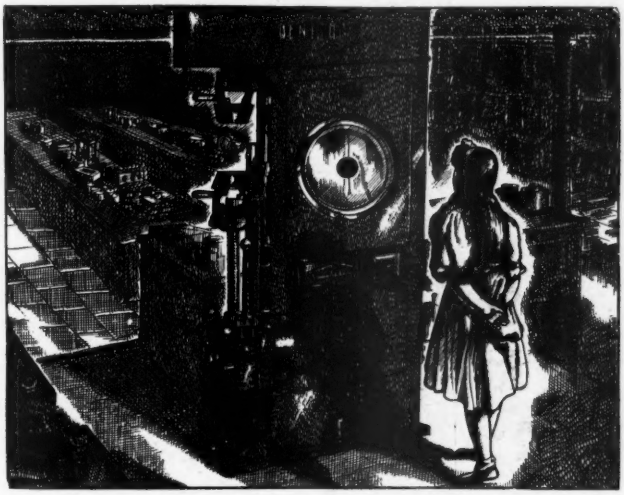
Alice in Plasticland—No. 4



Alice meets the Testing Machine

"Yes," said the testing machine to Alice, who was standing regarding it with some interest, "Plastics must be strong as well as ingenious. Some of them have tough jobs to stand up to . . . . . Think of those parts in fighter 'planes and tanks . . . . their's isn't an easy life by any means. But I put them through it and find out their breaking point, which is generally far higher than any strain which they are likely to be subjected to in the job for which they have been produced," and so saying, the machine literally clicked with satisfaction.

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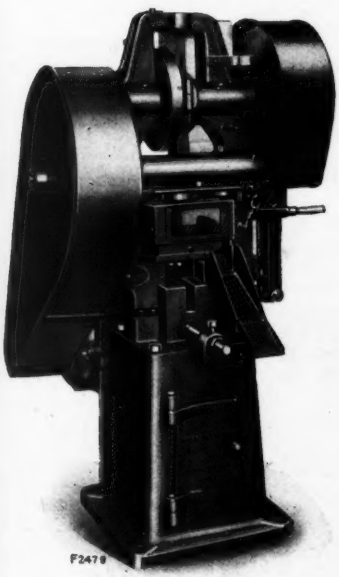

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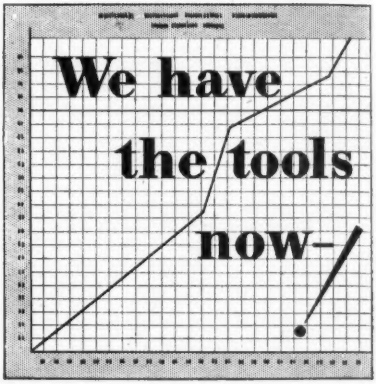

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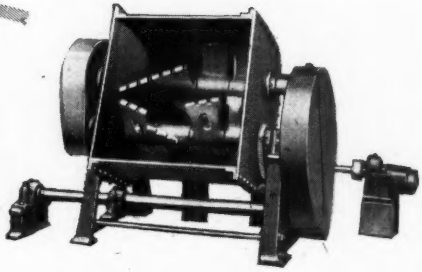

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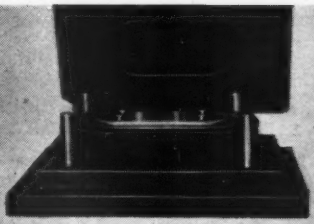

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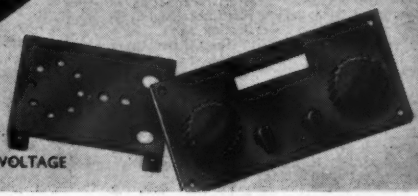

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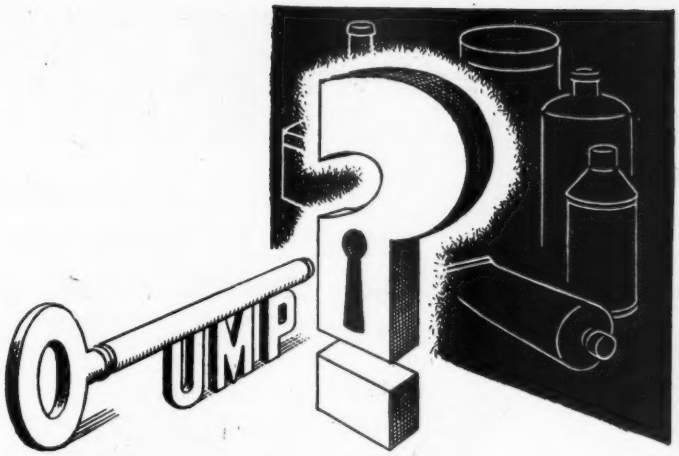

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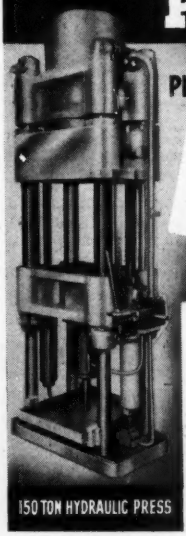

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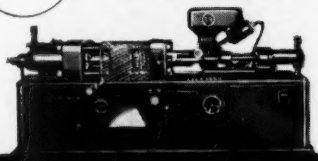

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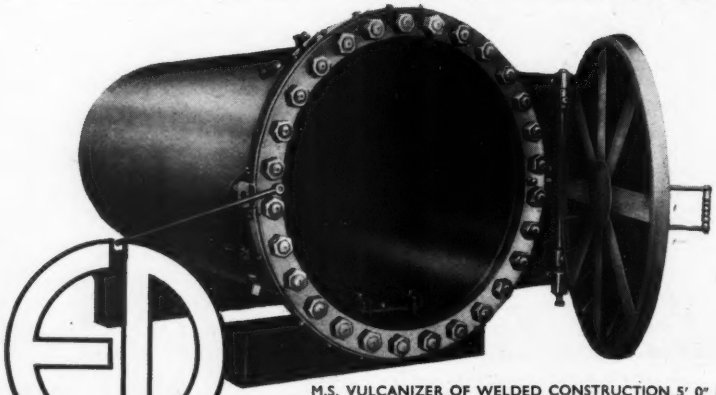

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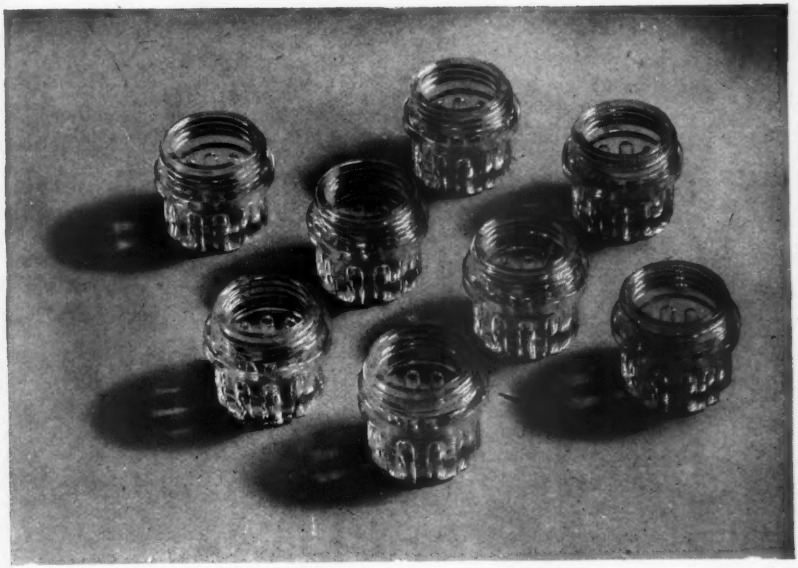

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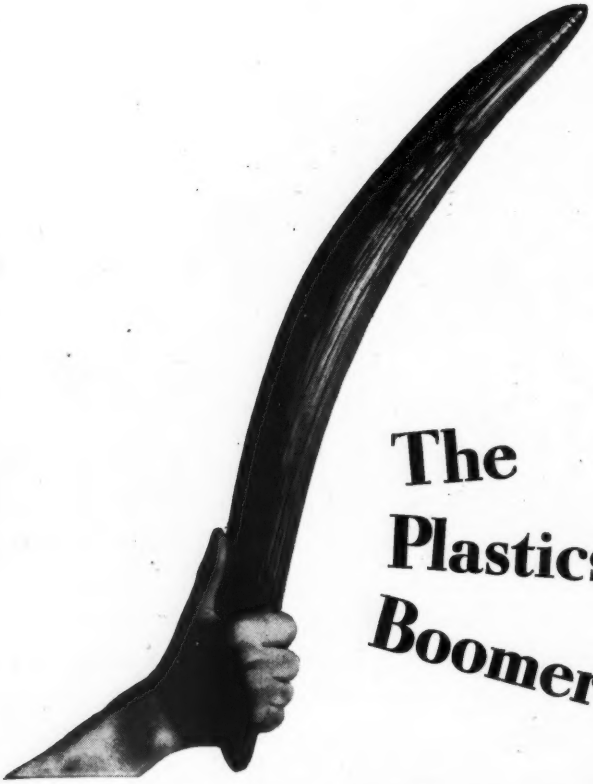

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WE'VE ALL MET the customer who expects a cup to bounce *when it's made of Plastics* but who shows no surprise when one of china comes to grief under similar treatment. The remedy for this attitude of mind lies in a better knowledge of the uses and abuses of plastics. Advertisements by Bakelite Limited and others in the industry are doing much to educate the public. The moulder, for his part, can safeguard himself by using only the correct grade of powder for the job. The range of Bakelite moulding powders continues to grow. It may be that in the newer grades is a powder more fitted for the work in hand — one that will provide our critical customer with the physical characteristics he needs. Bakelite Technical Staff will give every possible help. The fewer boomerangs the better for the Industry.

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Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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NOTICES

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SAVE PAPER

More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Wood as Raw Material

WHILE we are now given to talking of coal and petroleum as the great sources of chemicals (including plastics) of the present and the future, as, of course, no doubt they are and will be, yet it seems a pity that wood has receded into the background. At least the technologists of this country seem loath, in their talks, to consider it. This may be due to the fact that this country can never be a timber-growing country of any real importance. This we may take to be true if we make comparisons with the really large timber-growing countries like Canada, U.S.A., Sweden, Finland, and so on. But we have a very lusty research group in the Forest Products Research at Princes Risborough, and it would be interesting to know whether there is any chance of a resuscitation of our once interesting wood-distillation industry.

Even if we grow no wood an argument can be made out of the fact that since in pre-war days we imported enormous quantities of our timber for constructional purposes and always will, why can we not import for the creation of a new chemical industry based on wood? If our plastics and chemical industries are to go ahead on really big scales, we shall probably need large quantities of raw materials from sources additional to coal and petroleum.

People have almost forgotten that there were many interesting works in this country distilling wood to produce substances such as acetic acid, acetic anhydride, acetone, methyl alcohol and formaldehyde.

To-day most of them have disappeared, having met defeat from the price point of view at the hands of synthetic acetic acid and synthetic methyl alcohol, from which acetic anhydride and formaldehyde are now being manufactured. It is true that some few are still in existence, especially in places like Devon, in the form of isolated stills, for the production of charcoal, but taken all in all we may consider the industry a dying one here. It is probable, however, that several knowledgeable people in the chemical and plastics world regretted their almost total disappearance in war-time, when the synthetic varieties were not as plentiful as they desired.

On the other hand, many intelligent chemists seem aghast at the idea of wood alcohol and formaldehyde. About 1940, we ventured to regret their disappearance, especially the latter, for use in plastics manufacture, to a chemical acquaintance, but he withered us with "Wood formaldehyde is not suitable for making phenol-formaldehyde resins." We were so flabbergasted that we completely forgot to slay him by asking what sort of formaldehyde was available to Leo Baekeland in 1905.

However, if we are taking no interest in wood in this country, other countries are. It is part of chemical history now that Germany put up her first sugar from wood plant more than 10 years ago and that Canada is producing vanillin for flavouring in her wood-pulp plants, presumably from the lignin molecule.

Both the U.S.A. and Canada are hard at work developing the so-called lignin plastics as exemplified by Benalite and other sheet made by the Mason Corporation, and a recent Canadian visitor assured us that lignin can be produced at 2 cents per lb.

Certainly the extraction of "pure" lignin is exercising the brains of many experts; one of the most recent patents, B.P. 560,492, taken out by Ralph McKee, a well-known American chemical engineer, deals with the efficient removal of lignin from wood by digestion with special agents such as sodium and xylene sulphonate and its separation into fusible and

infusible lignins. The value of lignin for producing plastics by condensation with furfural is already well known and it shows promise too as a filler and anti-oxidant as well as an ingredient in paint and varnishes. Since lignin has been stated to be cheap and is present in most woody growth to the extent of nearly 30 per cent., we can see we have an important raw material. It is also claimed that the cellulose produced is an improvement on that made by older processes.

Canada, we are delighted to see, is not content to sit back and treat timber as English mine owners treated coal—merely as a mineral to be dug out of the earth and sold in the crude solid form to foreign countries in order that they could extract valuable chemicals from it to sell back to us at vastly increased prices. Canada, we believe, is regarding wood in much the same light as the U.S.A. regards petroleum. We may not be able to erect the vast factories necessary for bulky raw materials, but we should begin to study the matter technologically. We should benefit greatly thereby in ways that are just being foreseen.

Discoveries and Traffics

IT is not often that technical journals illumine their pages with political discussions. It is presumed infra dig., beneath contempt or at least outside their sphere of immediate operations to do so. More often than not such editors are not gifted with a profound knowledge of political philosophy. Having been assured by a politically knowledgeable friend that man was a political animal and that it was disgraceful for anybody, let alone a scientist (sic), not to interest himself in problems that are national or international, we attended a small meeting of enthusiasts who, in cricket parlance, can spin a pretty ball to off.

In deference, perhaps, to our presence, the talk was brought round to what might be called International Control of Science, by "control" meaning that new discoveries and new materials should not be allowed to appear on the market until examined and a balance struck of the benefit or harm that might be done to people in general or existing industries in particular, and, please, what were we in plastics doing about it?

This interest in science by politicians is not new, although, in general, it is concentrated on the problem of poison gas, which seems a good peg to hang the scientist.

No doubt when lions were introduced into the Roman arenas, gladiators groused that they were being done out of their jobs, but most probably the receipts at these vaudeville shows grew larger and everybody was eventually satisfied—with the exception of the early Christians.

Important arguments for control of science are taken from the Industrial Revolution, with the classical examples of inventions of spinning machines and the consequent unemployment. This was, on the whole, a temporary dislocation, and, as instanced by Lancashire, a period of high prosperity followed, intermingled with the doubtful prosperity of employment of children as half-timers.

Perhaps one of the best examples for those in favour of control is that given by the indigo industry. Practically all indigo used by the dyers in this country prior to 1890 was imported from India, where tens of thousands of workers had been employed in cultivating the indigo plant, in the gathering of the crude indigo, in its purification and its dispatch. The discovery of synthetic indigo in Germany and its large production by the Badische Anilin and Soda Fabrik in 1900 proved in the short space of five years the death-knell of the natural product. What had occupied the Indian workers in several large States was produced in a comparatively small works covering a few acres in a German town and tens of thousands were thrown permanently out of employment.

On the whole, there is little doubt that new discoveries (we exclude the obviously beneficial medical discoveries) not only

improve the lot of mankind directly, in providing more and better food, cheaper and better goods, improved housing, communications and amusements, but also so expand and create industries as to give better and increased opportunities for working. The machinery and fertilizers of the new agriculture, mass production of utility goods, refrigeration, radio and aircraft are all proof of this.

Plastics can dislocate no industry for many years to come—with perhaps two exceptions. Generally speaking, the output will be limited to the availability of raw materials, which is far below that available to the industries which employ metal, wood, clay, concrete, and so on, and, in any case, the plastic industry is mainly occupied in producing components for other industries. It does, however, presume that if it remains true to itself it can produce new materials that will benefit human kind directly, with new conceptions of manufacture, new designs and new beauty.

The two prominent exceptions where plastics may dislocate foreign industries are in synthetic rubber and in nylon manufacture. The former could obviously affect production in Malaya, Dutch East Indies and elsewhere, while nylon fibre may threaten Japanese and Chinese production of silk.

As for the first, we mentioned last month that the U.S. Government is already considering the effect of synthetic rubber manufacture on the condition of the native workers in rubber plantations. This is statesmanship.

Chance Memorial Lecture

Mr. Kenneth M. Chance, managing director and chairman of British Industrial Plastics, Ltd., speaking at the first of the Chance Memorial Lectures at the Grand Hotel, Birmingham, last month, advocated the utilization of coal to provide the country's organic chemical industry with its fundamental requirements (including power) from native resources at prices which would enable the country to take the lead in the manufacture of new products.

The lecture was the first of the Chance Memorial Lectures instituted by the Society of Chemical Industry, and those present included the Bishop of Birmingham (Dr. W. E. Barnes), the Mayor of Smethwick (Mr. F. Bodenham), Mr. K. H. Wilson (president of the Birmingham Chamber of Commerce) and a large number of representatives of national scientific societies. The chair was taken by Dr. William Cullen (chairman of the Society of Chemical Industry).

The lectures commemorate the association of the Chance family with the glass, plastics and chemical industries in the Midlands for the past 100 years.

Mr. Chance maintained that our first duty was to make the most of the sources of power available, and the first source of power in this country was coal. We had so neglected these invaluable native resources that although we had coal and limestone lying side by side, we shipped the coal to Norway to bring it back in the form of carbide or cynamide. We took coal from our richest seams to burn in our grates and under boilers and then abandoned the rest because it could not be mined any longer at a profit. Meantime the methane, the ethylane, the benzol, the phenols and all the other combinations that could be drawn from coal tar had either gone back into the atmosphere in smoke or were left abandoned in the ground.

In other countries power was derived from falling water. Where such falling water was fed by natural lakes and the fall was provided by Nature and was considerable, electricity could be generated very economically. Such conditions did not exist in this island. Yet up to £30,000,000 was to be guaranteed by the Government in the endeavour to create such conditions in Northern Scotland. For what purpose? asked Mr. Chance. If to provide light and heat to towns and villages, the cost seemed excessive. If to create power for industries, where were the raw materials for such industries to come from? Surely, it would be better to spend a fraction of that large sum in an endeavour to obtain a cheap source of power by gasifying coal underground in districts where everything was available for converting power to the benefits of mankind in raw materials, labour, housing and transport facilities.

Nothing could be well with a country whose industry was not founded upon the rock of cheap power. We must get down to fundamentals, secure our home market, not by tariffs, but by providing it with what it needed more cheaply and better than others could do it. Exports would follow.

The CLEANING of PLASTICS

With Special Reference to Cleaning After Fabrication Processes

By E. E. HALLS

THE operation of cleaning associated with metals at various stages of fabrication through the normally established processes of engineering is commonplace and universally accepted. "Clean" stock is purchased as far as practicable, that is iron and steel free from rust and scale, but well oiled or greased, and non-ferrous metals free from corrosion products. In cutting, drilling and tapping, milling, blanking and forming, or pressing, contamination with oils and greases used for cooling or lubrication occurs. Work becomes contaminated with swarf and dirt. Numerous cleanses are applied at various stages. If wire for automatic screw-cutting or heading machines has become rusted in store, it has to be cleaned either by acid pickling or by means of wire brush devices fitted to the machines. Drilled work, passed to subsequent operations where jigging is involved, must be cleaned to remove swarf, otherwise it will not nestle snugly in the jig and inaccurate machining results. Parts that have to be passed through inspection for detailed examination of an operation must be cleaned for convenience of handling, to permit of dimensional checking and avoidance of excessive wear and tear upon inspection instruments. When optical methods are employed, cleanliness is more than ever essential. Press work passing to heat treatment processes, such as intermediate annealing operations, must be cleaned to prevent grease and oil, and swarf, becoming "burnt on."

The foregoing features mainly concern machine operation contamination, oil, grease, swarf and incidental dirt. Chemical contamination also enters the picture, particularly fluxes in soldering and welding, these requiring removal quickly to eliminate the possibility of corrosion. Again, all work for "metal finishing," viz., electro-plating, lacquering, painting, enamelling, anodizing, bonderizing, etc., etc., demands meticulous cleaning by properly designed processes.

Comparison with Metal Cleaning

Briefly, then, with metals the necessity for cleanses becomes automatically associated with the operations concerned, and planning engineers specify appropriate procedures on each job layout card with any queries beyond those concerned with the nature of the clean itself. Plastics, however, do not promote the same response. Engineers in general envisage clean materials, no possible surface deterioration during storage, dry machining or blanking, no contamination from machines or from the box containers used in transport. Such visualization may be mainly correct in the ideal, but there are a thousand and one instances in practice where conditions fall a long way short of the ideal. There are many cases where lubricants are used; machine contamination does occur; swarf contamination is unavoidable; soldering operations upon metal inserts are entailed in numerous instances; and finishing operations (varnishing, lacquering and enamelling) do necessitate proper preparatory treatments. Again, metal swarf cannot by any means be precluded because often metal inserts are moulded in components with the intention of machining subsequently. Drilling, reaming and tapping are common among such processes. Lubrication is almost invariably associated with these operations; again the recommendation is stressed to give

attention in selecting the lubricant not only with its cutting and cooling virtues in mind, but with respect to its subsequent easy removal.

The electrical industries, and particularly the lighter electrical industries, viz., those concerned with the manufacture of communications apparatus, such as telephone and telegraphic gear, radio equipment and general instrument work, are perhaps more committed to the cleaning of plastic components than most of the trades that use them. Their problem, too, is complicated by the intricate nature of many of the components they have to make, the plurality of such items, the various grades and types of plastic used. Further, the facilities for cleaning that exist or can be fitted into an existing organization have to be used, and components rarely lend themselves to the design and establishment of a single automatic treatment. Under these circumstances, when phenolic resin products predominate, and are treated by means of coal tar solvent naphtha or with trichlorethylene, it is not unusual to find polystyrene components ruined by immersion in solvent naphtha or polymethacrylate articles wrecked in trichlorethylene. Such experiences are expensively purchased, the failures often occurring at the final stage of the work after much intricate machining has been completed.

Variety in Plastic Cleaning

General instructions on the cleaning of plastics are complicated by the number of types and to some degree by the range of grades within the same type. Again, most cases have to be considered on their merits because the possible contamination or degree of contamination will vary tremendously from one case to another.

In general it is assumed that most machining operations are carried out dry and that the work comes through them clean. This particularly applies to blanking operations; for example, in the blanking of insulators from synthetic resin bonded paper fabric or asbestos laminated, contamination is not anticipated because there is no swarf to adhere to the work, very little dust and no lubrication. However, some degree of contamination with oil and grease does occur from the press tools or from the machine, and in practice extensive contamination occurs at times due to the collection of the work in dirty boxes that may previously have been used for oily metal components. There are a number of applications where such contamination does not matter and would be ignored, but when electrical stresses on the assembly are of any magnitude and service conditions severe, such contamination, generally of unknown composition, is bound to be detrimental in lowering electrical properties, causing possible leakage, breakdown or corrosion of metal inserts.

In some cases applied finishes are specified, especially a surface moisture-proofing varnish having electrically non-tracking properties. When this is so, cleaning is essential in order to secure proper adhesion and full value from the varnish coating. Again, a large number of components may have to be marked by cellulose stencil spraying, by paint marking applied by rubber pads or gelatine transfer processes, or by printing processes of the Masseeley machine type. Here again, therefore, contamination, particularly of an oily or greasy nature, is bound to react adversely on the adherence of the marking.

When drilling, tapping and reaming are involved, inevitably dusty swarf accumulates and can only be removed by an appropriately designed operation, usually involving a solvent rinse.

Many of these operations, probably the majority of them, are performed dry, and oil and grease, except by inadvertent contamination, are not involved. On the other hand, many operators use oily or greasy lubricants to assist in these operations, some of them even using tallow. It is essential that these lubricants should be chosen so that they can be readily and completely removed and that it is ensured that none is retained by the material, either in crevices or by absorp-

tion. When these lubricants are properly chosen, there is no difficulty in their removal with a suitable solvent.

In the case of the bakelite plastics which are thermosetting and more or less immune to the effect of solvents, solvent cleaning is a relatively simple matter. When dealing with the thermoplastics, however, cellulose acetate, polystyrene, polymethacrylate, polythene, polyvinyl chloride, etc., considerably more careful selection is entailed and practice is restricted to one or two types of solvent which are without effect on the base material. This automatically makes it more important to ensure the minimum degree of contamination and that lubricants when used are chosen in relation to the trouble they will cause in their removal.

Apart from plain components, sub-assemblies or assemblies may have to be treated. Oil and grease contamination can occur during assembly and has to be removed, or in some cases even the minute traces of grease left by handling could be detrimental to electrical operation and require separate consideration. For example, silver-plated wire-wound tuning coils for high-frequency operation. Yet another type of extraneous matter that has to be removed by washing is soldering flux. In nearly all cases on assemblies and sub-assemblies, fluxing for soldering is restricted to resin or resin solutions because completely non-corrosive types only are acceptable. In the majority of cases it is not necessary to remove this flux, but in some instances it is desirable or even essential. Therefore solvents have to be selected and processes designed to do this without damage to the assembly.

There are, too, many jobs where corrosive fluxes of the zinc chloride base type are unavoidable, as when joining two refractory resistance wires. Here again the solvent has to be chosen in relation to the type of flux, and is usually restricted to water, methylated spirit, acetone, or something of that type. Consequently it will be seen that the cleaning of these parts must be classified on several bases. Primarily the classification will be based upon the composition of the material of which the component is constituted, and secondarily, in relation to the type of contamination that has to be removed. Further, on a few occasions where super cleaning has to be guaranteed, consideration has to be given to the purpose for which the cleaning is required. This may all seem very complex at first sight, but with logical handling it does simplify itself into a classified number of methods and a few solvents with fairly universal methods of application.

Available Organic Solvents

The cleaning of plastic components almost universally signifies the use of volatile organic solvents. Usually those employed for metal work are put to service for the plastics as well. Largely, they consist of high-grade solvents used for diluting or thinning of paints, lacquers or enamels; added to these are the specially designed cleaning solvents. The list thus embraces the following:—

(1) The paraffin oils.

(2) The petrols, or petrol derivatives, including the special benzenes and white spirits or turpentine substitutes.

(3) The coal tar solvents, either the naphthas themselves or, for specific purposes, the benzoles, toluoles or xyloles.

(4) Trichorethylene, usually the stabilized variety; or similar non-inflammable chlorinated hydrocarbons, such as methylene chloride or carbon tetrachloride.

(5) Cellulose lacquer thinners, usually the cheaper varieties containing high percentages of hydrocarbon diluent, yet still of high grade with respect to solvent qualities.

(6) The American turpentines themselves.

(7) The industrial methylated spirits.

(8) Acetone, amyl acetate, or similar pure solvents.

This list embraces a very wide range of

types, petroleum or coal tar hydrocarbons, chlorinated hydrocarbons, hydroxylic solvents miscible with water, pure solvents and mixtures. Water itself might be added to the list because there are possibilities for it. From the broad range, it is probably true to state that all the requirements for plastics can be satisfied efficiently and economically.

While the requirements for the cleaning solvent are mainly determined by each specific case, generalizations can usefully be made. The following may be considered as the chief criteria for the ideal cleaner:—

(a) Readily obtainable, easy to handle and inexpensive.

(b) Simplicity in application and easy to remove.

(c) Effective solvent action upon the contamination that has to be removed.

(d) Absence of solvent action upon the plastic treated.

(e) Minimum of absorption by the plastic treated.

(f) Devoid of any tendency to leave a residual film, whether this be of difficult volatile liquid, or solid, or traces of an acidic or alkaline nature.

(g) Devoid of any tendency to leave the surfaces treated electrically weak, e.g., low surface insulation resistance.

(h) Freedom from fire hazard.

(i) Freedom from toxicity and health hazard.

(j) Optimum volatility, so as not to be excessively volatile and a nuisance in the general shop, with difficulties in exhausting, or too slow for rapid production.

(k) Devoid of objectionable odour.

Obviously, no medium can fully satisfy these requirements and the best compromise has to be sought. Before dealing with the solvents in detail, and then the plastics for which best suited, a few broad statements can be made upon the solvents named against the criteria listed.

General Characteristics

With the exception of the pure solvents, all satisfy the cost aspect, and all really fulfil the availability and manipulability requirements. Excluding paraffin oil, genuine turpentine and the less-volatile pure solvents, all can be easily removed. Regarding solvent action upon the contaminant, all are solvents for oil, all are non-solvents or very poor solvents for soap, and few are solvents for resin, methylated spirit and trichlorethylene being notable exceptions, and American turpentine and acetone less suitable solvents for this material. Each has to be separately studied in relation to individual plastics in relation to solvent attack, and each type of plastic considered with respect to absorption. Paraffin oil and American turpentine excepted, none of them, if purchased in grades of good quality, leaves troublesome films. Again, with the same exceptions, no deterioration is caused in surface electrical properties provided they are properly dried off. When the drying off is indifferent, methylated spirit is the most likely to produce low surface insulation due to its hydroxylic nature. With the exception of chlorinated hydrocarbons, all are highly inflammable, a feature that must be taken care of by appropriate safety precautions. The lower-boiling solvents, the more volatile coal tar hydrocarbons, the petrols and acetone, are more dangerous in this direction than the higher-boiling members. Toxicity must also be safeguarded by exhausts. None of them is violently toxic, but most of them sufficiently so to warrant full attention to the point if used continuously. The chlorinated hydrocarbons are, perhaps, the worst of the group, these increasing in toxicity in the order carbon tetrachloride, trichlorethylene, methylene chloride. The coal tar derivatives are probably next worst, with toxicity decreasing with increase in molecular weight, from benzole to xylole. American turpentine and white spirit are, perhaps, more irritant to the hands than most of the other inflammable solvents of the series. Volatility will be dealt with in detail, but, for most purposes, petrol, methylene chloride and acetone would be considered too volatile, and all

other items satisfactory for general usage. American turpentine and white spirit may be too slow for some applications. Finally, with regard to odour, none is thoroughly objectionable, all are characteristic, and some may be objectionable to operators of extra sensitivity. The petrols and coal tar solvents may tend to be sickly with prolonged exposure; the chlorinated solvents are probably the least favourable for smell, and the cellulose and pure solvents have specialized smells rather than being repulsive in any way. Tabulated test data are given to show the detailed characteristics of the solvents.

The properties of paraffin oil are typically represented by the data given in Table 1. It is a neutral hydrocarbon solvent of the petroleum series, the least inflammable of them, but its boiling range extends too high to be satisfactory for drying off without risk of leaving an oily film. Further, a characteristic odour is retained by the work, and this is not too pleasant. This solvent is extensively used for the rough cleaning of metal work, to avoid excessive fire risks, with the object of removing heavy oil and swarf contamination. It can upon occasion be advantageously used for plastics for the same reason, but its employment is strictly limited to such purposes.

Table 2 characterizes the lighter petroleum hydrocarbon solvents. All are neutral and practically free from residue. All are highly inflammable, and petrol itself is very rarely employed by virtue of its great volatility and undue fire risk. The light benzine is the " middle " fraction of petrol, and it is quite extensively used, generally for immersion cleaning followed by natural drying off at room temperature. Applied with a cloth, it is also used for localized cleaning. It is good, but fire precautions must be observed. The heavy benzine is usually a little more variable in characteristics, and a little heavier in residue than the light benzine. It is not an essential item, white spirit, the higher fraction, being more usual if the higher boiling range can be tolerated. It is used for localized cleaning as well as for immersion cleaning. It requires a longer time than the light benzine for drying off, or, alternatively, air blast can be resorted to to assist in this direction.

Table 3 deals with the commercial coal tar solvent naphthas. It will be observed that they are more dense than the petroleum hydrocarbons. The medium naphtha is the one most extensively employed. It is intermediate between

Table 1.—Characteristics of Paraffin Oil.

Sample No.	1	2
Specific gravity at 15.5°C.	0.820	0.006
Flash point, degs. F., closed	103	100
Boiling range, degs. Cent., per cent. by volume distilling between:—		
180–190	6	7
190–200	11	8
200–210	21	15
210–220	20	20
220–230	20	16
230–240	13	12
240–250	8	12
Above 250	1	10
	100	100

Table 2.—Characteristics of Petroleum Solvents.

Sample No.	1	2	3	4
Type	Petrol	Light benzine	Heavy benzine	White spirit
Specific gravity at 15.5°C.	0.737	0.740	0.735	0.800
Residue on evaporation %	0.010	Traces	0.013	0.005
Boiling range, degs. Cent., per cent. by volume distilling:—				
Below 50	8	Nil	—	—
From 50– 60	6	1	2	—
60– 70	8	3	5	—
70– 80	9	5	4	—
80– 90	7	16	4	—
90–100	5	37	5	—
100–110	5	31	15	—
110–120	7	7	15	—
120–130	6	—	30	—
130–140	8	—	13	—
140–150	9	—	4	12
150–160	5	—	2	40
160–170	5	—	1	21
170–180	6	—	—	11
180–190	6	—	—	6
190–200	—	—	—	3
Above 200	—	—	—	Nil
	100	100	100	100

Table 3.—Characteristics of Coal Tar Solvent Naphthas.

Sample No.	1	2	3
Type	Medium	Heavy	Heavy
Flash point, degs. F. (closed)	Below 60	100	122
Specific gravity at 15.5°C.	0.851	0.854	0.842
Residue on evaporation %	Traces	0.10	0.18
Boiling range, degs. Cent., per cent. by volume distilling:—			
Below 110	2	—	—
From 110–120 ..	11	—	—
120–130 ..	30	—	—
130–140 ..	36	—	—
140–150 ..	17	2	—
150–160 ..	4	27	—
160–170 ..	—	67	1
170–180 ..	—	4	43
180–190 ..	—	—	47
190–200 ..	—	—	9
	100	100	100

Table 4.—Characteristics of Trichlorethylene (Stabilized).

Sample No.	1	2
Specific gravity at 15.5°C.	1.462	1.461
Residue on evaporation %	0.005	0.001
Boiling range, degs. Cent., by volume distilling ..	100% at 86 to 87% C.	90% at 86 to 90°C. 10% above 90°C.
Reaction	Faintly alkaline	Faintly acid
Alkalinity expressed as ammonia %	0.0035	—
Acidity expressed as hydrochloric acid %	—	Less than 0.0005

light benzine and white spirit for boiling range, is less irritant to the hands than is white spirit, and is very suitable for immersion cleaning. All the naphthas are neutral solvents, the medium one is residueless, but the heavy types are apt to be variable.

The trichlorethylenes are shown in Table 4. Their main virtue is that they can be employed without fire risk. Almost invariably they are used in specially designed vapour plants, or combined liquor-vapour plants. In the latter the work can be quickly rinsed in cold or hot liquid solvent, the loose solid contamination thus removed, and then flushed in the vapour section. The low boiling point of the solvent enables thermosetting plastics, phenolic and amino, to be safely treated. The plants are ideal for removing resin flux residues after the tinning or soldering of terminal tags inserted in or attached to these plastic components.

Trichlorethylene, in common with most highly chlorinated hydrocarbons, tends to develop acidity due to the formation of hydrochloric acid under the influence of moisture and/or light. This objectionable feature is prevented in the commercial grades of the solvent by the inclusion of a very small percentage of an addition agent called a "stabilizer." Stabilized trichlorethylenes should therefore be employed. The quantity of addition is exceedingly small. In this country, the practice differs from that in America. Hence British trichlorethylenes are very faintly alkaline, which alkalinity appears to be due to ammonia or similar compounds. American trichlorethylene of the stabilized variety is very minutely acidic. Both the stabilized materials remain stabilized upon storage or in use, in distinct contrast with the non-stabilized grades. Attention can be drawn to B.P. No. 378,084/1931 (I.C.I., Ltd.) on the subject of stabilization of chlorinated hydrocarbons. The additions claimed in this are a little free fatty acid and soap. Oleic acid and alkali soap are specifically mentioned and cross-reference made to B.P. No. 155,595.

Methylene chloride is used on the Continent in place of trichlorethylene for metal degreasing. Its greater volatility and lower boiling point are the attractive features. Losses can be safeguarded by properly designed plants, and the greater rapidity of operating offsets the higher cost of the material. It has been used in this country on an industrial scale. For the thermosetting plastics, the lower boiling range makes it specially attractive. Table 5 shows its characteristics; as far as is known, commercial stabilized grades do not exist.

For reasons of convenience and easy

Table 5.—Characteristics of Methylene Chloride.

Sample No.	1	2
Specific gravity at 15.5°C.	1.333	1.320
Residue on evaporation %	Nil	Nil
Boiling range, degs. Cent., per cent. by volume distilling between:—		
35–40	25	—
40–45	20	25
45–50	12	18
50–55	7	22
55–60	6	18
60–65	5	7
65–70	5	10
70–75	6	—
75–80	6	—
80–90	8	—
	100	100

availability, cellulose lacquer and enamel thinners are often used for metal cleaning, both for general purposes and for cleaning for organic finishing. There is much to be said for the practice because these solvents are exceptionally good cleaners, this being ensured by balanced composition of hydrocarbon, ester and ketonic solvents. Again, some workers use a 50/50 mixture of cellulose thinner with 64 OP methylated spirit. In order to show the nature of the cellulose thinners, a range of the less expensive varieties are given in Table 6. It will be seen that Nos. 1 and 2 are approximately one part nitrocellulose solvent with three parts coal tar hydrocarbon diluent, and that No. 5 is about a 50/50 mixture of N.C. solvent with petroleum hydrocarbon diluent. No. 3 is a little more complex, but No. 4 is basically similar to Nos. 1 and 2, except that the actual ingredients are chemically different. They are all virtually free from acidity and from residue. They can advantageously be used on many thermosetting plastics, but their composition must be clearly known before contemplating other uses.

On account of the fact that a number of synthetic enamel finishes are often applied to phenolic resin base materials, some of these finishes being air dried and some stoved, the characteristics of the American turpentines are included in Table 7. These solvents are sometimes used to dilute the enamel to spraying consistency and therefore likewise to wipe the work over before enamelling. It will be seen that both the gum and wood varieties give appreciable gummy residue and that boiling temperature is relatively higher.

Table 8 illustrates the industrial methylated spirits. These are among the

Table 6.—Physical and Chemical Characteristics of Inexpensive Cellulose Thinners.

Sample No.	1	2	3	4	5
Specific gravity at 15.5°C.	0.870	0.863	0.862	0.872	0.816
Residue on evaporation per cent.	0.01	0.005	Traces	0.01	Nil
Boiling range, degs. Cent., per cent. by volume distilling:—					
From 70– 80	—	—	33	—	6
80– 90	—	—	9	—	8
90–100	35	—	10	15	10
100–110	10	10	35	20	18
110–120	15	90	13	50	22
120–130	15	—	—	10	34
130–140	25	—	—	5	2
	100	100	100	100	100
Composition per cent. by wt.:—					
Butyl acetate	25	28	—	—	45
Coal tar naphtha	75	72	—	—	—
Toluene	—	—	64	72	—
Methylated spirit	—	—	16	—	—
Ethyl acetate	—	—	20	—	—
Amyl acetate	—	—	—	28	—
Petroleum benzine	—	—	—	—	55
	100	100	100	100	100

Table 7.—Physical Characteristics of American Turpentines

Sample No.	1	2
Type	Genuine gum turpentine	Steam-distilled wood turpentine
Specific gravity at 15.5°C.	0.865	0.862
Residue upon evaporation, per cent.	1.6	2.3
Acid value, mgm. KOH/gm.		
(a) Alcoholic extract	0.18	0.07
(b) Aqueous extract	0.04	0.04
Boiling range, degs. Cent., per cent. by volume distilling between:—		
Below 150	Nil	Nil
150–170	97	95
Above 170	3	5

cheapest of solvents, yet clean and very pure, for all intents and purposes free from acidity or residue. They are less highly inflammable than the hydrocarbon solvents. The industrial methylated spirits are ethylalcohol denatured with 5 per cent. of wood alcohol. They are clear, colourless liquids and are marketed on a basis of water content or over proof strength. Table 8 gives typical characteristics of the three strengths, 64, 68 and 74 O.P. The first of these is the most commonly used one, the other two being chosen when minimum water content is desirable.

Acetone is a solvent frequently maintained in the factory store, and is particularly used for washing phenolic plastics by means of a cloth prior to such operations as stencil marking with cellulose enamels. Typical test values are given in Table 9.

In general, acetone is considered to be too volatile for this type of work, although it can be improved by using it admixed with amyl or butyl acetate. Characteristics of commercial grades of these are shown in Tables 10 and 11.

Table 9.

	No. 1	No. 2
Specific gravity at 15.5°C.	0.800	0.797
Residue on evaporation %	Traces	0.002
Acidity (calc. as acetic acid) %	0.003	0.010
Boiling point, degs. C.	56	56

Table 8.—Characteristics of Industrial Methylated Spirits, Showing Water Content Values of Strengths 64 to 74 O.P.

Sample No.	1	2	3
Grade	64 O.P.	68 O.P.	74 O.P.
Typical test values:			
Specific gravity at 15.5°C.	0.821	0.812	0.798
Residue on evaporation %	0.003	0.001	0.002
Acidity, calc. as ascetic acid %	0.001	0.003	0.002
Nominal water content:			
Per cent. by volume	6.5	4.2	0.8
Per cent. by weight	9.6	6.4	1.2

In practice, however, it is obviously simpler to use a selected cellulose thinner.

The relative volatilities of these various solvents can be visualized from their boiling points or ranges. However, several methods have been employed for

Table 10.

Butyl Acetate.	
Specific gravity at 15.5°C.	0.878
Distillation range	95% between 120–126°C./5% above 126°C.
Residue	0.0017%
Ester value	93.5% by weight
Acidity	0.07 m/grms. potassium hydroide/grm.

evaluating evaporative rates in a manner representative of their conditions of application. In general, they enable the solvents to be positioned in relation to one another and give concordant relative results, although they may differ fundamentally in the technique employed. Some use "thick" and some "thin" layers, and generally they involve weight/time determinations. Thick layers entail a lengthy test period which is not only objectionable purely from the time factor angle, but also on account of the difficulty in maintaining constant evaporation conditions of temperature, draught, surface area and such like

Table 11.

Amyl Acetate.	
Specific gravity at 15.5°C.	0.860
Acidity calculated as acetic acid	0.018%
Residue	0.0018%
Distillation range	98.5% by volume between 125 and 145°C.
Ester content	98.8% by weight

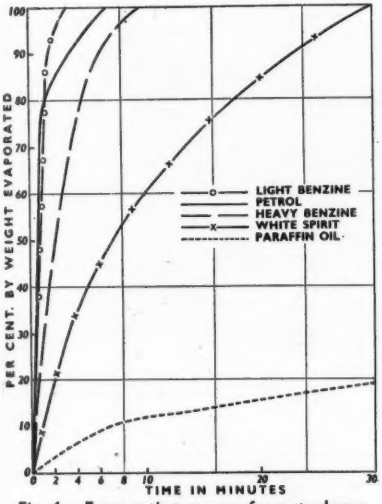


Fig. 1.—Evaporation curves for petroleum solvents.

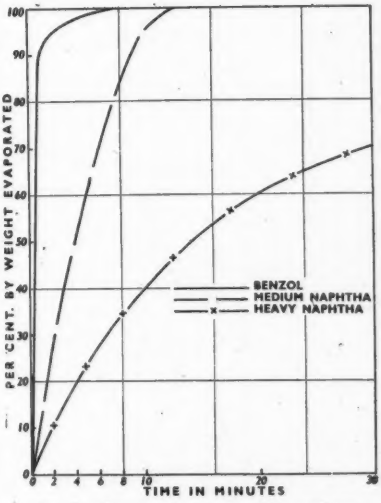


Fig. 2.—Evaporation curves for coal tar solvents.

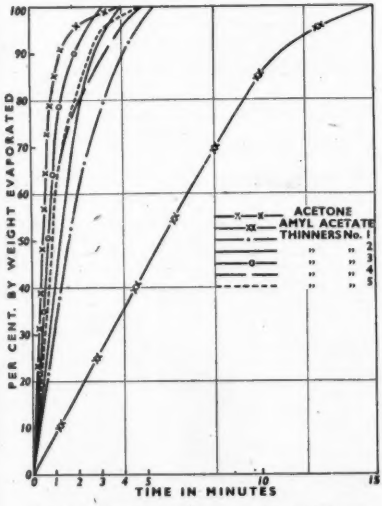


Fig. 3.—Evaporation curves for cellulose thinners.

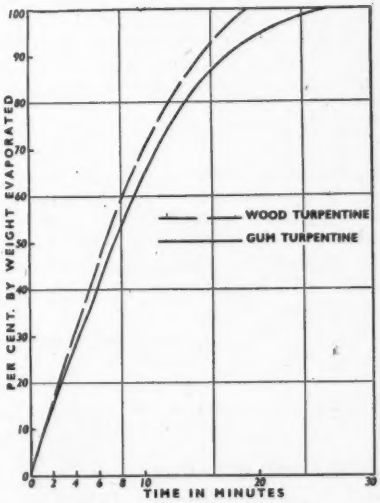


Fig. 4.—Evaporation curves for turpentines.

critical features. A very rapid method is employed for determining the volatility of, in effect, thin films of solvents, and details of it are briefly as follow:—

A weighed, normal, circular laboratory filter paper, diameter about 5 ins., is soaked by immersion in the solvent to be examined, withdrawn and excess

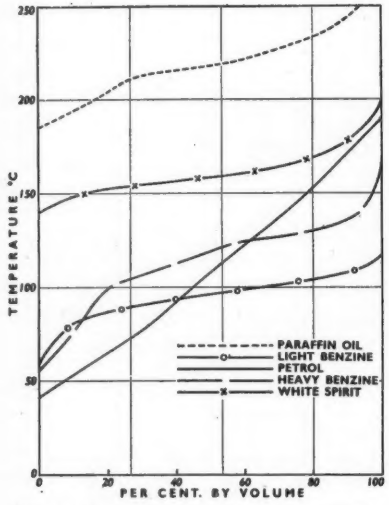


Fig. 5.—B.P. curves for petroleum solvents.

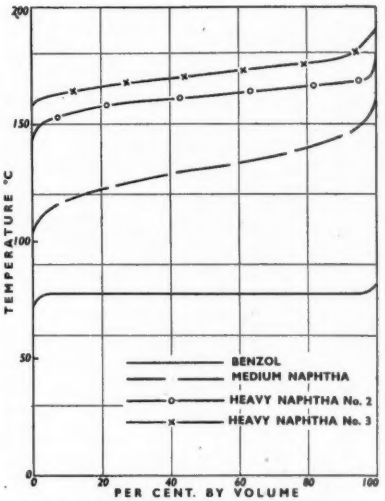


Fig. 6.—B.P. curves for coal tar solvents.

solvent quickly removed by pressing the wet paper lightly between filter papers. It is then immediately suspended from the arm of an analytical balance. Weighings are taken at close intervals of time (half-minute periods are usual). The balance case is kept open during the test; the ambient temperature should be recorded. The time interval between removal of the test paper from the filter papers and suspending in the balance should be negligible, and the time of suspension taken as the initial time, the corresponding weight being extrapolated from the subsequent readings. A curve is plotted correlating percentage loss in weight and time to give a visual picture of volatility.

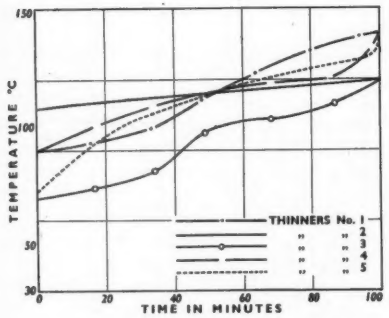


Fig. 7.—B.P. curves for cellulose thinners.

Volatility curves are given in Figs. 1 to 4 for some of the solvents discussed, the petroleum derivatives, the coal tar hydrocarbons, the cellulose thinners and, finally, the American turpentines. To show the link between volatility and boiling point or range, boiling curves for the same groups of solvents are given in Figs. 5 to 8.

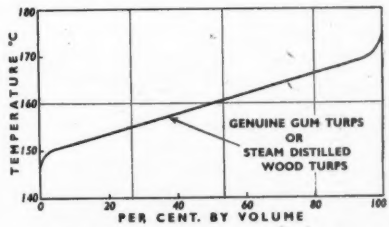
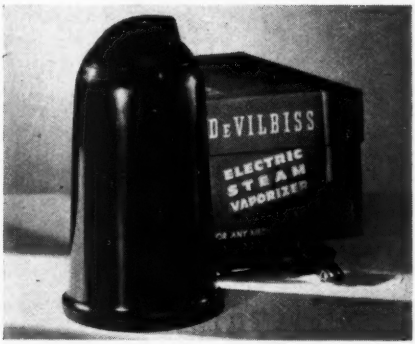


Fig. 8.—B.P. curves for American turpentine.

(To be continued)

Moulded Plastic Vaporizer

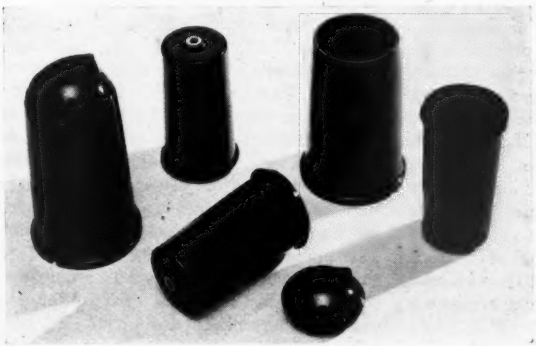


Noteworthy American production in Durez resin.

EXCEPT for the electric heating element and porcelain washer, this is an all-plastic vaporizer. The parts are moulded of a Durez 75 type plastic material. This is high chemical resistant with very low moisture absorption, and gives a very lustrous finish. It may even be machined or sanded and buffed, if necessary. It is resistant to the average medicant used, to hot water, and to any alcohol solution required for cleaning.

The parts moulded of this Durez plastic include the inner and outer shells, the cover, shield plate over the heating element, assembly bolt head, and the locking nut. The space between the inner and outer shells acts as an efficient insulator and prevents the outer shell from becoming too hot to handle. A cup is moulded into the inside of the cover to hold the medicated cotton. Steam circulating within the inner shell absorbs the medication and it passes out the vapour through a small opening in the cover. This opening is so designed that it permits only a steady flow of vapour and does not throw drops. The vaporizer is easy to clean and keep clean. The level mark to which water should be filled is moulded in. (The vaporizer operates one hour or longer without refilling, automatically shuts off when water level falls below the midsection of the electrodes.) A shield over the electrodes provides complete protection against a short circuit or shock.

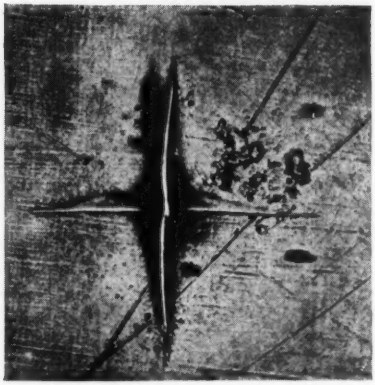
The moulded parts are fabricated for the De Vilbiss Company, U.S.A., by Peerless Molded Products Company and Plastics Division of Reynolds Spring Company from plastic material supplied by Durez Plastics and Chemicals, Inc.



Breakdown of vaporizer showing six plastic components.

Surface Hardness of Organic Glasses

Special requirements and technique for testing scratch resistance of transparent plastics are described. (After Perkuhn "Luftfahrtforschung" 1943/20/297). Reasons are advanced for abandoning the better-known indentation methods.



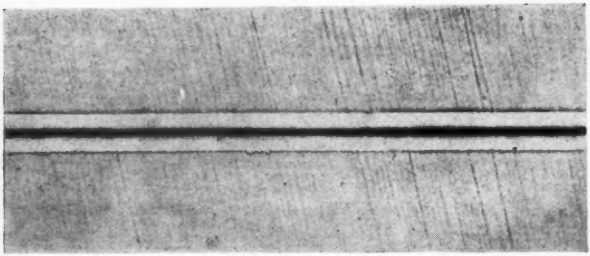


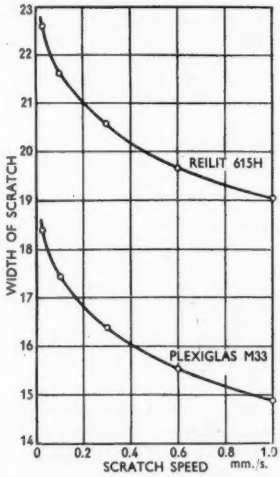
Fig. 1 (left).—Scratch, in Plexiglas M.33, with cone of 120 degrees included angle. (Magnification 120 linear.)

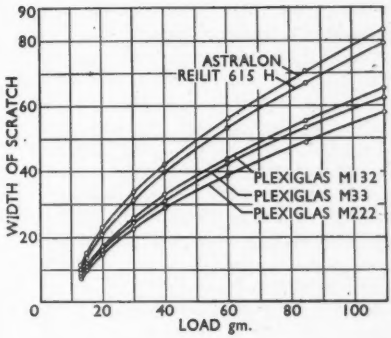
Fig. 2 (above).—Vickers impression in Plexiglas M.33. Magnification 360 linear); note ill-defined boundaries.

IN order to determine the resistance of organic glasses to scratching, as, for example, through air-borne sand, the usual hardness tests as practised for metals, for example, Brinell, Vickers, Rockwell, are not entirely suited, in so far as such methods usually demand the application of high loads, with the production, consequently, of very deep impressions which overshadow the influence of the surface of the material. For this reason it was decided for the purpose of these experiments to resort again to the scratch hardness test which, permitting, as it does, the use of very small loads, seemed ideally suited to the determination of surface hardness.

The experiments were conducted with Plexiglas M.33, M.132, M.222, Reilit and Astralon, using a Zeiss Diritest machine (see "Maschinenbau," 1938/17/527), It became apparent from the results of tests that the scratch hardness value obtained on these materials by this method depends on the speed of scratching, hence the hand-operated scratch mechanism was replaced by a mechanically operated device. By the use of a suitable electric motor, it was found possible to adjust the speed of scratching to various fixed values.

Test pieces measuring 40 mm. by 40 mm. were cut from 3 mm. sheets of the materials under examination, specimens being taken from various points on the sheet. The scratching device used consisted of a conical diamond point with an included angle of 120 degrees. Measurements were carried out over the temperature range 0-45 degrees under thermostatic conditions with control within ± 1.5 degrees.





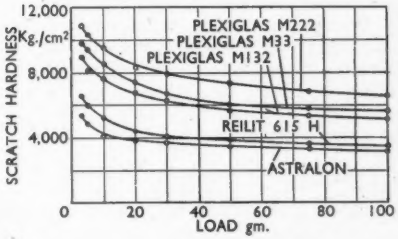


Fig. 3 (above.)—Curves for scratch width in relationship to scratch speed. (Load 10 gm.) Fig. 4 (above, right).—Scratch width in relationship to load. (Scratch speed 0.3 mm. per second). Fig. 5 (right).—Scratch hardness in relationship to load.

Comparison between the scratch hardness test and the Vickers hardness test showed that the former method has, technically, many advantages. Scratching produces marks with sharp uniform edges, which, by means of suitable technique, can be measured to limits of ± 1 per cent. Apart from this, elastic hysteresis effects, which are liable to become confusing in the case of ordinary indention tests, are so small as to be negligible in the case of scratch hardness. Even after a period of 60 mins., change in dimension of the scratches is still so small as to lie within the limits of the method. The extreme accuracy of measurement which may be achieved is such that most minute differences in hardness may be determined, as, for example, that between Plexiglas M.33 and M.132.

For 10 independent measurements made on each of these materials, and on others, using a load of 20 gms., Plexiglas M.33 gave a scratch width of 24.4 μ with a variation of ± 1 per cent.; M.132, 25.6 μ, with a variation of ± 1 per cent.; and M.222, 23.0 μ, with a variation of ± 1.0 per cent. Using the Vickers hardness method, on the other hand, the effect of the somewhat fuzzy diagonals gives an error of ± 1.5 per cent., hence minute differences in hardness cannot be determined. The following values were actually obtained for diagonal lengths using a load of 20 gms. and a loading

time 60 secs.:—M.33, 46 $\mu \pm$ 1.5 per cent.; M.132, 46.4 $\mu \pm$ 1.5 per cent.; M.222, 43.0 $\mu \pm$ 1.5 per cent. The scratch hardness test determines only the plastic component in the deformation which results during the test, all elastic reaction being completed after the passage of the scratch point over the particular part of the material affected.

In Fig. 3 is shown a curve for scratch width in relationship to speed of scratching. The width of scratch diminishes with increasing speed of scratching, due to growing resistance offered by the material to the scratch tool.* For speeds above 0.3 mm. per sec. the diamond scratch tool commences to chatter, hence for all subsequent tests a scratching speed of 0.3 mm. per sec. was selected as giving sharply defined edges.

In Fig. 4 is presented a curve for width of scratch in relationship to hardness. In the case of all materials investigated, increase of load produced an increasing width of scratch, although such increase became less marked when still further loading was applied.

In the case of Plexiglas and Reilit, it was not possible to determine any difference in hardness along different directions in the sheet, any variations found lying well within the limits of accuracy of measurement. In the case of Astralon, however, tests carried out in

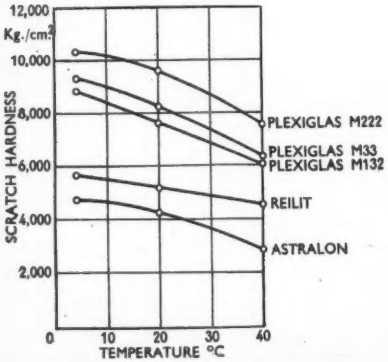


Fig. 6.—Scratch hardness in relationship to temperature. (Load 10 gm.)

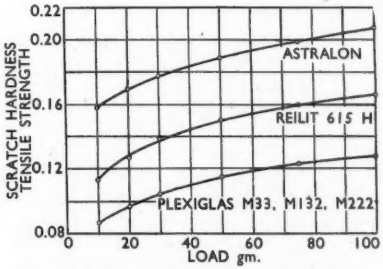


Fig. 7. — Curves for various types of organic glass showing influence of test load on the relationship between scratch hardness and tensile strength. Tensile strength was determined at a loading rate of 300 kg./cm.²/min.

directions at right angles on the sheet gave noticeably different values, probably as a result of calender effect.

In the case of the static hardness test, hardness is expressed in terms of stress per unit area. Correspondingly, Ehrenberg (see "Z.f.Metallkunde," 1941/33/22) defines scratch hardness H in terms of the load per unit sliding surface, thus $H = \frac{8P \sin \gamma/2}{b^2}$ where P = load, b = width of scratch, γ = included angle of the scratching tool. Although this mode of expression does not correspond exactly to the physical processes involved, nevertheless, as will be shown subsequently, it produces useful workable results.

As shown in Fig. 5, with increasing load the scratch hardness appears to fall, first rapidly, and then more slowly. The more rapid drop is to be attributed to the differing elastic reactions of the surface layers of the material as compared with those of the material lying farther beneath these. With increasing depth of scratch, the effect of surface stresses as compared with stresses in the deeper masses of the material becomes constantly less. Thus, by correct choice of

* This explanation, we feel, is not altogether adequate, as the resistance offered to a cutting tool frequently diminishes as cutting speed is increased. It would seem more likely that some softening of the plastic occurs with consequent direct adhesion, i.e., welding.

Table 1.

Material	Scratch width		
	Along Specimen	Across Specimen	Diagonally
Plexiglas M222 ..	28.8 28.8 29.0	28.7 28.8 28.8	28.8 28.7 29.0
Plexiglas M132 ..	32.8 32.8 32.6	32.7 32.8 32.8	32.8 32.6 32.8
Plexiglas M33 ..	31.2 31.4 31.4	31.4 31.4 31.5	31.4 31.2 31.3
Reilit 615H ..	40.0 40.2 40.1	40.4 40.2 40.2	40.2 40.4 40.4
Astralon	42.8 43.2 43.0	44.0 44.2 44.0	43.4 43.4 43.2

load, either pure surface hardness can be determined or that of the deeper lying material. When determining resistance of organic glasses to scratching it is recommended that the lower loads be selected, although, for the sake of accuracy, loads below 10 gms. should not be used. With loads over 100 gms. burring of the edges of the scratch makes accurate measurement of its width no longer possible.

For any given material, it is known, in general, that a definite relationship exists between Brinell hardness and tensile strength. Similarly, between scratch hardness and tensile strength, it is possible between 4 degrees and 40 degrees C. to derive a similar relationship. The relationship of tensile strength to scratch hardness at constant load within the temperature range given is almost constant, as indicated in Table 2. The relationship between the conversion factor for scratch hardness to tensile strength in relationship to load is shown in Fig. 7.

The conversion of scratch hardness figures for the organic glasses to tensile strengths is both rapid and accurate to within $\pm$ 2.5 per cent.

From the practical standpoint, it is obvious that many of the apparently theoretical considerations taken into account here are, in fact, of importance. In service, the organic glasses may be used under a wide variety of conditions. First as to temperature: here current demands may call for operation in environments ranging from -40 degrees C. to $+120$ degrees C. Secondly, the incidence of abrasive particles will cover extremes ranging from direct normal impact at all velocities, to high angular velocities of grazing impact (as, for example, in the case of sandstorms in desert areas).

Table 2

Material	Temp. °C.	Scratch Width μ	Scratch Hardness Kg./cm.²	Tensile Strength Kg./cm.²*	T.S./H.	T.S./H. (Mean value)
Plexiglas M222	4	14.6	10.300	900	0.087	
	20	15.2	9.559	820	0.086	
	40	17.1	7.550	660	0.087	
Plexiglas M132	4	15.8	8.830	760	0.086	
	20	17.0	7.630	675	0.087	0.087
	40	19.0	6.100	540	0.088	
Plexiglas M33	4	15.4	9.300	800	0.086	
	20	16.4	8.210	720	0.087	
	40	18.6	6.370	560	0.08	
Reilit	4	19.7	5.670	650	0.114	
	20	20.6	5.200	595	0.111	0.113
	40	22.0	4.550	520	0.114	
Astralon	4	21.5	4.770	760	0.159	
	20	22.8	4.250	660	0.155	0.157
	40	27.6	2.890	460	0.159	

* Determined for loading rate of 300 Kg./cm.²/min.

World's Industry Employs Plastics

ELECTRICAL

Cellulose acetate butyrate tape as primary insulation for wires and cables forms the subject of a paper by Allen at a recent technical session of the Wire Association Convention ("Wire and Wire Products," 1944/19/37). The material is cast in sheet from any thickness from 0.0005 in. to 0.0016 in. and in widths from $\frac{1}{8}$ in. to 40 ins. In laminated form—two layers—it can be built up to 0.0032 in. in thickness. Either type, single or laminated, can be supplied with a vinyl acetate mixed ester opaque white coating to give visual control and to facilitate sealing of the laps. Results of intensive research on the physical properties of this material by the Eastman Kodak Co. are presented in the paper. **Coating of wires with polyamide resins** is covered in U.S. Patent 2335930. The wire is brought into contact with an aqueous suspension of the resin, wetting being promoted by appropriate small additions of sodium lauryl sulphate. **Insulation of copper wire and cable with Neoprene** is subject to stringent control, due to shortage of this material in U.S.A. The essential requirements of the war and metal industry in Buna will in future be met. Koroseal and Vinylite will also be in adequate supply for priority users. ("Wire and Wire Products," 1944/19/244.) Over the past two years in Great Britain and U.S.A., and for a period of some five or more years in Germany, considerable masses of technical data have been collected on synthetic insulating media; these are found in appropriate periodicals.

AIRCRAFT

Glass fibre reinforced plastic has been developed by the Owens-Corning Fiberglass Corporation. Experimental samples show tensile strengths of over 25 tons to the sq. in., and impact strengths of over 20 ft. lb. The material may be moulded into aircraft structural units at low pressure and without the use of abnormally expensive moulds. The structure of the material has been compared to that of wood, consisting of cellulose fibres bonded with lignin. ("Scientific American," 1944/170/207.) The same issue of this journal (p. 207) refers to a **cork substitute** prepared by the Northern Regional Research Laboratory of the Department of Agriculture, Peoria, Illinois. Again on page 214 the journal presents a general account of what has been achieved in the utilization of **wood and plastic tooling** in the American Aircraft Industry. **New casting resin "Toolite"** (thermosetting) has been used for the structural members of radial drills at Consolidated Vultee Aircraft Corporation. The material is lighter than magnesium, has an abrasive strength up to 8 tons/sq. in., has a commendable resistance to impact, and withstands temperatures up to 400 degrees F. **Plastic-bonded plywoods in aircraft construction forms** basis of data presented by Hiscocks in the "Engineering Journal," 1944/27/4 (extracted in the "Engineer's Digest," 1944/5/131). Reference is made in particular to bonding and glueing techniques and to bend radii. This latter point has long engaged the attention of sheet-metal technicians.

GENERAL ENGINEERING

Bearings designed primarily for use where ball bearings have previously been employed, are the "Delarmet," a product of De La Rue Plastics, Ltd., Avenue Works, Walthamstow Avenue, London, E.4. The outstanding feature of the design is that the load is taken on a plastic material which has been subjected to a special colloidal graphiting process that imparts to it practically permanent lubricating properties. As with a ball bearing, there is an inner and outer steel member, the plastic forming the separating medium. These bearings are made in two main types, one being of the rigid class and the other possessing considerable self-aligning characteristics, but they are not intended for use where high rotational speeds are common. In the machining of the outside member of the bearing and the diameter of the hole through the centre member, dimensions and tolerances, common to ball races, are maintained so that they can be substituted for ball races without introducing difficult or, perhaps, inconvenient machining operations. There is a large number of types in the standard range, but special bearings can be supplied to meet any particular requirement. Full technical information and the service of its advisory staff can be obtained from the maker at the address given. **Cut-off discs and grinding wheels** bonded with synthetic rubber are being manufactured by P. de Sanno and Sond, Phœnixville, Penn. These wheels have proved to be superior under test to similar wheels bonded with natural rubber. Long life, high cutting speed, good finish and minimum burning are said to be obtained ("Machinery," New York, 1944/50/180). In the same journal is mentioned a **grinding wheel for finishing moulded synthetic rubber products.** The wheel is said to cut faces cleanly and coolly, giving no pulling on the softest rubber compound.

MISCELLANEOUS

Leeds Arts and Crafts Exhibition at the Leeds Art Gallery during a Youth Festival Week contained a large section devoted to plastics. Many of the objects displayed, which included necklets, were beautifully designed. **Flexible printing plate** comprising paper laminated with Plaskon glue has been developed by Toland and Bassist, of the Plastolith Co. After bonding, the sheets are coated with Plaskon, the printing side then being treated with three layers of a special alcohol/clay emulsion. Moisture-proof regenerated cellulose may, according to Neil Owens, be employed as a seal for wounds to protect them from external bacterial infection. **Plastics** progress in **U.S.A. during 1943** is reviewed by Kline in "Mechanical Engineering," 1944/66/235. The account comprises the following groupings—moulding and fabricating, aircraft, war applications, mechanical properties, testing specifications. The bibliography appended to the account contains 200 references. In the same issue of this journal Liska reviews **advances made in rubber during 1943;** a full bibliography of 133 references is appended. Attention is called to an early but somewhat inaccessible reprint from "Kunststoffe" for July, 1937. It was issued under the title "Neue Formen fur Gebrauchsgegenstande aus Kunstharz," and contains numerous critical studies of designs of mouldings for electrical and general purposes. It is especially well illustrated and the matter is by no means out-dated. **Uses of lignin** form subject of report of investigation detailed in "Modern Industry," Vol. 6, 1943, p. 42 (October 15). (Abstract in "Metals and Alloys," Vol. 19, 1944, p. 200, January.) Lignin-cellulose plastic moulding compositions and plastic fillers are made into boards. Lignin is available in large quantities from paper mill waste. In plastics, lignin is usually recombined with cellulose.

Physical Behaviour and Testing of Plastics (Contd.)

By H. BARRON, Ph.D.

In the June issue the author discussed the general importance of testing plastics and described the available methods for evaluating flow characteristics, tensile and compressive strengths, impact resistance, flexural strength volume and surface resistivity, water absorption, and electrical breakdown strength. He concludes his discussion in this issue with tests for power factor, softening point, shrinkage, cold flow, hardness, water permeability and viscosity.

Permittivity and Power Factor

Permittivity or dielectric constant is the ratio of the capacity of a condenser having the plastic as the dielectric compared with the same condenser having air as the dielectric. It will vary with the frequency of the alternating current which is used.

The power factor is the ratio of the power loss in the plastic when used as the dielectric compared with the total power transmitted through the condenser (product of the applied voltage and the resulting current). It varies with the frequency.

In the past, apart from the few materials intended for electrical insulation, these properties have not been of particular interest. Latterly they have gained new significance even where these properties are poor. The reason is the introduction of high-frequency heating methods. For these purposes high dielectric constant and high power factor are quite desirable features, in great contrast to normal electrical applications. In fact, those materials with particularly good

Table 9.—Dielectric Constants for Plastics.

Material	Dielectric constant			
	At 50 cycles	At 10^3 cycles	At 10^6 cycles	Over 10^6 cycles
Phenol-formaldehyde (no filler)	5.0–6.0	4.0–5.0	4.5–5.0	4.5–7.0
Phenol-formaldehyde (wood flour filler)	5.0–12.0	4.0–8.0	4.5–8.0	4.5–8.0
Phenol-formaldehyde (mineral filler)	5.0–20.0	4.5–20.0	4.5–20.0	4.5–20.0
Phenol-formaldehyde (scrap fabric filler)	5.0–10.0	4.5–6.0	4.5–6.0	4.5–7.0
Phenol-formaldehyde (paper laminated)	—	—	3.6–5.5	4.5–8.0
Phenol-formaldehyde (fabric laminated)	—	—	4.5–7.0	4.5–7.0
Phenol-formaldehyde (asbestos laminated)	—	—	—	—
Phenol-formaldehyde (cast)	5.0–10.0	—	5.0–8.0	4.5–7.0
Phenol-formaldehyde (glass fabric laminated)	—	—	—	—
Phenol-furfural (wood flour filler)	—	4.0–8.0	6.0–7.5	—
Urea-formaldehyde (moulded)	—	—	—	—
Melamine (filled)	6.5–10.0	—	7.0	—
Cellulose acetate (sheet)	3.5–7.5	3.5–7.0	3.0–5.0	—
Cellulose acetate (moulded)	4.5–6.2	4.5–6.0	4.0–5.0	—
Cellulose acetate butyrate	3.5–6.5	—	3.2–6.0	—
Cellulose nitrate	6.7–7.3	—	6.15	—
Ethyl cellulose	2.8	2.5–3.5	2.0–3.0	—
Polystyrene	2.6	2.6	2.6	2.9
Polythene	2.3	2.3	2.3	2.3
Polyvinyl chloride (plasticized)	4.0–12.0	4.0–12.0	—	—
Polyvinyl chloride acetate (no filler)	3.2–3.5	—	3.0–3.3	4.0
Polyvinyl chloride acetate (filled)	—	4.7	4.0	—
Polyvinyl formal	3.8	3.8	3.7	—
Polyvinyl butyral	—	—	—	—
Polyvinyl alcohol	—	—	—	—
Polyvinylidene chloride	3.0–5.0	3.0–5.0	3.0–5.0	3.0–5.0
Methyl methacrylate (cast)	3.5	3.2	3.2	—
Methyl methacrylate (moulded)	3.0–3.1	3.3–3.5	3.1–3.3	—
Nylon	3.2	3.3	3.6	—
Casein	—	—	6.2–6.5	—

Table 10.—Power Factors for Plastics.

Material	Power factor			Radio frequencies
	At 50 cycles	At 10^3 cycles	At 10^6 cycles	
Phenol-formaldehyde (no filler)	.05–.10	.025–.06	.015–.04	.005–.05
Phenol-formaldehyde (wood flour filler)	.04–.30	.04–.15	.035–.10	.01–.1
Phenol-formaldehyde (mineral filler)	.10–.30	.10–.15	.005–.10	.1–.1
Phenol-formaldehyde (scrap fabric filler)	.08–.03	.08–.20	.04–.10	.05–.1
Phenol-formaldehyde (paper laminated)	—	—	.02–.05	.015–.05
Phenol-formaldehyde (fabric laminated)	—	—	.02–.08	.05–.1
Phenol-formaldehyde (asbestos laminated)	—	—	—	—
Phenol-formaldehyde (cast)	.025–.20	.005–.08	.01–.045	.005–.05
Phenol-formaldehyde (glass fabric laminated)	—	—	—	—
Phenol-furfural (wood flour filler)	—	.04–.15	.035–.10	.01–.06
Urea-formaldehyde (moulded)	.03–.15	.035–.065	.03–.04	—
Melamine (filled)	.07–.17	—	0.04	—
Cellulose acetate (sheet)	.02–.07	—	.04–.09	—
Cellulose acetate (moulded)	.01–.6	.02–.06	.04–.06	—
Cellulose acetobutyrate	.014–.06	—	.018–.05	—
Cellulose nitrate	.06–.15	—	.07–.10	—
Ethyl cellulose	—	.005–.025	.007–.03	—
Polystyrene	.0001	.0001	.0001	0.0002
Polythene	—	—	—	—
Polyvinyl chloride (plasticized)	0.136	—	—	—
Polyvinyl chloride acetate (no filler)	.01–.04	.014	.018	0.018
Polyvinyl chloride acetate (filled)	.04–.048	—	.01–.03	—
Polyvinyl formal	.007	.008	.009	—
Polyvinyl butyral	.06	—	—	—
Polyvinyl alcohol	—	—	—	—
Polyvinylidene chloride	.03–.08	.03–.05	.03–.05	—
Methyl methacrylate (cast)	.06	.06	.025	0.02
Methyl methacrylate (moulded)	.05–.06	.06–.07	.02–.03	0.02
Nylon	0.01	.015	.022	—
Casein	—	—	.050	—

electrical properties, e.g., polystyrene and polythene, cannot readily be heat treated with high-frequency current.

From the point of view of radio communications the behaviour of the leading materials at extremely high frequencies is of the highest importance.

To determine these values B.S.S. 903 requires a flat sheet of material greater than 8 ins. in diameter, and between 3 and 6 mm. thick. Electrodes and a guard ring are fitted to the test piece. These are made up of graphite and brass backing plates. The lower electrode is a 20-cm. circle. The upper electrode is also circular, 15-cm. diameter, and is surrounded by a guard ring 15.4-cm. internal diameter. These areas are painted over with a graphite dispersion and then exactly covered by the brass plates. The measurements are determined by means of a Schering bridge, in which the test piece and electrodes form one capacitor. The most widely used test frequency is 800 cycles per second.

The complete details of the test and methods of calculation are to be found in B.S.S. 903.

The characteristics of a number of other non-plastic materials which find applica-

Table 11.—Properties of Some Non-plastic Electrical Insulating Materials.

Material	Specific gravity	Tensile strength p.s.i.	Dielectric constant	Power factor		
				50 cycles	1 kc.	1 mc.
Mycalex	3.5	6,000– 8,000	6.8	—	.006	.003
Steatite	2.5	8,000–10,000	6.1	.01	.004	.003
Porcelain (dry process)	2.3	2,000– 3,000	6.2–7.5	.02	.01	.007
Mica	2.8	—	7.0–7.3	.0003	.002	.0002
Quartz (fused)	2.21	7,000–10,000	4.2	.003	.003	.0003
Glass	2.25	—	4.5	—	.005	.002
Hard rubber	1.15	4,000– 7,000	2.3	.01	.01	.005–.009
Slate	2.8	5,000	6–8	—	.009	—

tion in the electrical field are quoted in Table 11. They may form the basis for comparison with the plastics. The one feature that should perhaps be emphasized is that apart from hard rubber (or ebonite) none of these materials can be machined. This contrasts with the excellent machining behaviour of most plastic materials.

Influence of Temperature on Plastics

By definition the behaviour of plastics towards temperature is one of their most critical properties. This behaviour imposes the principal limitations upon the use of plastics. From the practical point of view, other thermal considerations are no less important. In moulding operations the coefficient of expansion and subsequent shrinkage upon cooling will be a major factor. The amount of heat required and the nature of heating equipment will be influenced by the thermal conductivity of the material, and so on.

Thermosetting resins, being infusible, are not subject to marked flow with rise in temperature. On the other hand, thermoplastic materials will begin to flow as the temperature is raised. It is one of the defects of most thermoplastic materials that the flow temperature is lower than would be desired. With one or two exceptions, this is general. In some instances it is possible to increase the softening point by the judicious addition of filling materials, etc. This practice almost invariably introduces other disadvantages.

Softening Point

The most important characteristic is the softening point or the temperature at which thermal deformation begins. Above this temperature the material becomes progressively softer and flows more readily until a condition approximating to a melting point is reached, when the material behaves substantially as a fluid. There is no definite softening point. As the temperature rises the material changes from a more or less rigid condition with barely any flow to a softer comparatively fluid state. With most plastics this softening range is very wide. It is a characteristic of typically amorphous materials. The exceptions are the materials which show crystallized behaviour, namely, nylon, polythene and polyvinylidene chloride. Each of these has a fairly sharp melting point and a very narrow softening range.

There are a number of different methods employed to determine the softening point. One method is based on the familiar ball-and-ring test, such as is widely used for bituminous materials and waxes, etc.

The Ball-and-ring Method for Softening Point

The equipment consists of a brass ring $\frac{5}{8}$-in. inside diameter, 3-32-in. thick and $\frac{1}{4}$-in. deep. This is supported so that the lower surface is exactly an inch above a flat brass plate. The plastic is either melted and poured into this ring, or may be moulded into the ring. The assembly is placed into a glass vessel containing distilled water. A steel ball $\frac{3}{8}$ in. in diameter, weighing 3.5 grams, is placed in the middle of the material in the ring. The temperature of the water is then raised at a rate of 5 degrees C. per minute. The temperature recorded when the steel ball touches the top of the lower plate is taken as the softening point. For softening points above 80 degrees C. glycerine is used instead of water.

Hall's Apparatus

Hall describes a method (" Plastics," August, 1942, p. 273) related to the ring-and-ball procedure. The softening point determinations on the thermoplastics were made on a plunger type of test, using the apparatus shown in Fig. 9. It comprises a framework carrying two horizontal plates, $\frac{1}{2}$ in. apart, the upper one 0.20 in. thick, having a central hole of $\frac{1}{2}$ in. diameter. The specimen, reduced by machining to $\frac{1}{16}$ in. thickness, is laid over this hole and the plunger brought to rest upon it. The plunger is $\frac{1}{4}$-in. in diameter, and operates freely between two guides. The platform at its upper end is loaded to a weight of

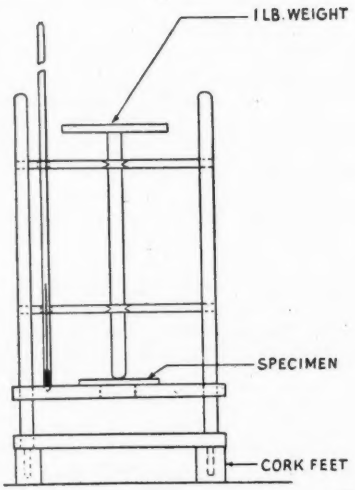


Fig. 9.—Halls's apparatus for testing soften-point.

1 lb., inclusive of the plunger itself. The whole set-up can be heated gradually by means of a water bath at a rate of 5 degrees C. per minute. The softening point of the specimen is read as that at which the extruded sheath of plastic reaches the lower plate, or at which the extruded dome fractures, whichever first occurs. This temperature is indicated by a thermometer in the bath, which, of course, must be kept stirred to maintain uniformity of heat throughout.

Plastic Yield

Another important value is the plastic yield of a cantilever test piece under a fixed load as the temperature is increased. Plastic yield is the total deformation of a bar-shaped specimen stressed under cantilever loading at a given temperature for a given time. This test features in most specifications. In British Standard Specifications 771 and 903 it is described as a proof test.

A bar 200 mm. long and 15 mm. square section, with a V-notch across one side 5 mm. from the end is mounted horizontally as a cantilever. It is rigidly clamped at one end (see Fig. 10) so that A = 45 mm. and B = 150 mm. The stirrup is made to distribute the load uniformly across the width of the test piece. The test piece is heated for 15 mins. at the test temperature (see below), the height of the stirrup above a fixed point measured, and a load of 450 g., including the weight of the stirrup, is applied by means of the stirrup. The test piece is kept under load at the test temperature for six hours, at the end of which period, with the load still in position, the height of the stirrup is remeasured. It must not have dropped more than 5 mm. The method is adapted to find the actual yield temperature, i.e., when the yield amounts to 5 mm. This is done by repeating the tests at increasing temperature intervals until the yield is reached.

In the case of the Martens test, the load is much higher, being equivalent to

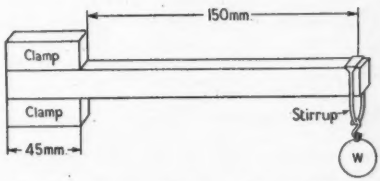


Fig. 10.—Arrangement for plastic yield test.

50 kg. per sq. cm. The set-up is similar, but the temperature is raised 50 degrees C. per hour until the deflection reaches 6 mm. The Martens test is much more rapid than the British test, but is said to give higher results.

Shrinkage

The shrinkage of plastics, particularly during the moulding cycle, is obtained by direct measurement. The B.S.S. test moulds a specimen 4 to 5 ins. in diameter and 0.125 in. thick, under prescribed conditions. After cooling, the dimensions are measured and the difference between these values and the original values gives a measure of the shrinkage.

There will be other forms of shrinkage. Where plastics contain plasticizers, etc.,

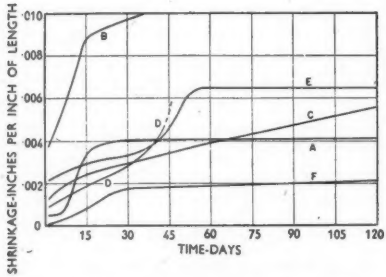


Fig. 11.—Dimensional stability of plastics at 50° C.

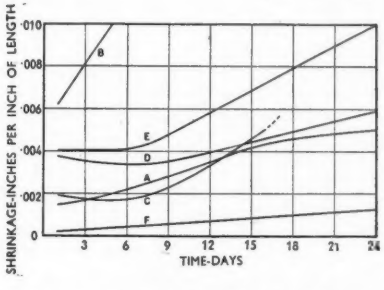


Fig. 12.—Dimensional stability of plastics at 70° C.

A, General purpose P.F. resin; B, Cellulose acetate; C, Cellulose acetobutyrate; D, Methyl methacrylate; E, Ethyl cellulose; F, Polystyrene. (According to Goggin.)

which are volatile there will, in due course, be some losses and corresponding shrinkage. When plastics are subjected to continuous raised temperature, there may be continued polymerization or internal chemical effects which may be shown by shrinkage. This aspect has been studied by Goggin. His dimensional stability curves are reproduced in Figs. 11 and 12.

Cold Flow

In its narrowest sense " cold flow " is considered to be the degree of deformation which a material will experience under its own weight. It becomes increasingly more apparent as the temperature rises. Where it is at all marked, then such materials are very restricted in use. However, under applied loads most materials tend to undergo a certain

Table 12.—Maximum Operation (Continuous) Temperatures for Plastics.

Material	Maximum operation temp. °C.
Phenol-formaldehyde (no filler)	120
Phenol-formaldehyde (wood flour filler)	175
Phenol-formaldehyde (mineral filler)	230
Phenol-formaldehyde (scrap fabric filler)	120–175
Phenol-formaldehyde (paper laminated)	100–150
Phenol-formaldehyde (fabric laminated)	100–175
Phenol-formaldehyde (asbestos laminated)	200–230
Phenol-formaldehyde (cast)	72
Phenol-formaldehyde (glass fabric laminated)	250
Phenol-furfural (wood flour filler)	230
Urea-formaldehyde (moulded)	72
Melamine (filled)	150–200
Cellulose acetate (sheet)	60–80
Cellulose acetate (moulded)	60–80
Cellulose acetobutyrate	60–90
Cellulose nitrate	60
Ethyl cellulose	60–80
Polystyrene	65–75
Polythene	80
Polyvinyl chloride (plasticized)	65
Polyvinyl chloride acetate (no filler)	110
Polyvinyl chloride acetate (filled)	—
Polyvinyl formal	70–100
Polyvinyl butyral	60
Polyvinyl alcohol	100
Polyvinylidene chloride	130
Methyl methacrylate (cast)	60–70
Methyl methacrylate (moulded)	60–70
Nylon	—
Casein	—

Table 13.—Thermal Expansion of Plastics.

Material	Thermal expansion (in./inch/°C.)
Phenol-formaldehyde (no filler)	—
Phenol-formaldehyde (wood flour filler)	.000037–.000075
Phenol-formaldehyde (mineral filler)	.000025–.000040
Phenol-formaldehyde (scrap fabric filler)	.000020–.000060
Phenol-formaldehyde (paper laminated)	.000017–.000025
Phenol-formaldehyde (fabric laminated)	.000017–.000030
Phenol-formaldehyde (asbestos laminated)	.000017–.000025
Phenol-formaldehyde (cast)	.000028
Phenol-formaldehyde (glass laminated)	—
Phenol-furfural (wood flour filler)	.000030
Urea-formaldehyde (moulded)	.000025–.000030
Melamine (filled)	—
Cellulose acetate (sheet)	.000140–.000160
Cellulose acetate (moulded)	.000140–.000160
Cellulose acetobutyrate	.000130–.000150
Cellulose nitrate	.000120–.000160
Ethyl cellulose	.000100–.000140
Polystyrene	.000070–.000080
Polythene	—
Polyvinyl chloride (plasticized)	—
Polyvinyl chloride acetate (no filler)	.000069
Polyvinyl chloride acetate (filled)	—
Polyvinyl formal	—
Polyvinyl butyral	—
Polyvinyl alcohol	—
Polyvinylidene chloride	—
Methyl methacrylate (cast)	.000080
Methyl methacrylate (moulded)	.000080–.00009
Nylon	.0001
Casein	.000080

amount of flow over a period of time. Another way to express this is the creep under load. The extent to which this occurs is clearly a matter of great significance where dimensional uniformity and stability must be maintained. In some instances this property can be an advantage, as in packings, seals, etc. But in most applications it is a disadvantage. As might be expected, cold flow is most marked in thermoplastic materials.

Bunn and Hopkins have made a study of the relative cold flow of a number of plastic materials. The results are summarized in the following table:—

Table 14.—Measured Percentage Decrease in Height of ½-in. Cube held for 24 hours at 100°C. between Parallel Plates under Load of 1,000 lb.

Material	Cold Flow %
Phenolic plastics	0.4
Urea plastics	0.7 to 7
Cast Phenolics	10.0
Hard rubber	0.5 up to 80
Vinyl plastics	1.0 up to 32
Acrylic resins	1.0 up to 50
Polystyrene	1.0 up to 22
Cellulose-acetate plastics	2.0 up to 64
Benzyl cellulose	76.0

Hardness Number

The hardness of plastics is a matter of some importance for several applications. In many respects it gives some indication of such factors as scratch resistance.

So far as testing is concerned, the materials must be considered in two categories, the soft yielding rubber-like plastics and the hard rigid materials. Different methods are employed to assess the hardness in each instance. The general principle is to consider indentation caused by a known load.

The Brinell method of hardness is carried out by pressing a steel ball into the surface under test. Usually in metal practice a ball with a 1 cm. diameter is pressed under a force of between 500-3,000 kilos. In the case of relatively soft materials such as plastics, a much smaller ball and smaller load is applied. Common practice uses a 2.5-mm. ball with a load of 25 kilos.

As might be expected, methods adopted for the softer rubbery materials follow rubber practice. The Shore durometer is widely employed. In Great Britain the hardness equipment designed by the R.A.B.R.M. has been generally adopted and is recommended in B.S.S. 903. For example, the test recommended for polyvinyl chloride compounds among British cable-makers is as follows:—

Test pieces are 10 mm. thick and of sufficient area for the tests to be taken at not less than 12 mm. from the edge. The upper and lower surfaces are as flat and smooth as possible.

The polyvinyl chloride compound test piece is supported on a horizontal, rigid surface. Temperature is maintained at 20 degrees C. A plunger terminating in a rigid ball 3/32 in. (2.38 mm.) diameter is pressed for 5 secs. vertically on to the test piece, the load on the ball being 30 g., and the position of the plunger noted. An additional load of 535 g. is then applied and maintained for 30 secs.,

Table 15.—Brinell Hardness of Plastics.

Material	2.5 mm. ball 25 kg. load
Phenol-formaldehyde (no filler)	30–45
Phenol-formaldehyde (wood flour filler)	—
Phenol-formaldehyde (mineral filler)	—
Phenol-formaldehyde (scrap fabric filler)	32–40
Phenol-formaldehyde (paper laminated)	24–40
Phenol-formaldehyde (fabric laminated)	30–45
Phenol-formaldehyde (asbestos laminated)	30–45
Phenol-formaldehyde (cast)	30–45
Phenol-formaldehyde (glass fabric laminated)	—
Phenol-furfural (wood flour filler)	35–40
Urea-formaldehyde (moulded)	(50 kg.) 48–54 (500 kg. 1 cm. ball)
Melamine (filled)	—
Cellulose acetate (sheet)	8–15 (10 kg.)
Cellulose acetate (moulded)	
Cellulose acetobutyrate	
Cellulose nitrate	
Ethyl cellulose	
Polystyrene	20–30
Polythene	—
Polyvinyl chloride (plasticized)	—
Polyvinyl chloride acetate (no filler)	15–25
Polyvinyl chloride acetate (filled)	—
Polyvinyl formal	—
Polyvinyl butyral	—
Polyvinyl alcohol	—
Polyvinylidene chloride	—
Methyl methacrylate (cast)	18–20
Methyl methacrylate (moulded)	14–21
Nylon	—
Casein	23

and the position of the plunger is then read again. The part of the plunger in contact with the test piece shall nowhere exceed 3/32 in. diameter. During the loading periods the apparatus is gently vibrated, preferably by means of a buzzer, to overcome any friction. The movement of the plunger, i.e. the difference between the two readings, expressed in 100ths of a mm., is the Hardness Number.

Water Permeability of Plastics

In the case of films of material it is particularly important that they should be impermeable to water. In many cases such films are used as a protection against moisture, for moisture-proofing. The first inclination is to think that this behaviour will follow closely the water absorption property. Actually this is not the case. An entirely different set of conditions applies. The structure of the material plays a great part. The outstanding example is the case of polystyrene, whose water absorption over indefinite periods is nil. Yet a film of polystyrene is relatively permeable to water. The best material as regards water permeability is polyvinylidene chloride. This neither absorbs water, nor does it allow it to pass through even the thinnest of films.

Comparative tests have been made on films of various plastics. The results are shown in Hall's table (Table 16).

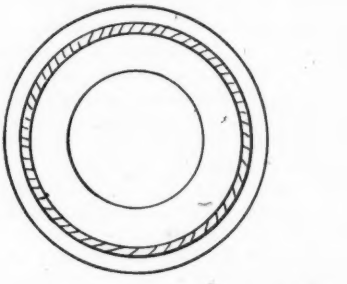


Fig. 13.—Hall's assembly for water-vapour permeability test.

Tests were made by sealing the specimen over a brass cup containing water, using a moisture-proof sealing compound. This set-up is shown diagrammatically in Fig. 13. The assemblage was weighed initially and at intervals during exposure to a dry atmosphere in a desiccator containing calcium chloride as drying agent. The approximate area of specimen exposed and through which water vapour could pass was 1 sq. in. The specimen was, therefore, submitted to conditions

Table 16.—Water Permeability of Films.

Material	Film thickness (")	Water milligrams/sq. in. 1 day	7 days
Cellulose acetate (sheet)	0.002	168	1,040
Cellulose acetobutyrate	—	—	—
Cellulose nitrate	—	—	—
Ethyl cellulose	0.001	1,000	—
Polythene	0.0025	0.7	5
Polystyrene	—	—	—
Polyvinyl chloride (plasticized)	—	—	—
Polyvinyl chloride acetate (no filler)	—	—	—
Polyvinyl chloride acetate (filled)	—	—	—
Polyvinyl formal	—	—	—
Polyvinyl butyral	0.010	5–8	—
Polyvinyl alcohol	—	—	—
Polyvinylidene chloride	0.0014	nil	nil
Nylon	—	—	—
Regenerated cellulose	0.001	750	3,000
Moisture-proof regenerated cellulose	0.001	20	145
Rubber hydrochloride	0.001	5	33

of 100 per cent. humidity gradient, that is, 100 per cent. humidity within the cup, 0 per cent. in the outside atmosphere, at laboratory temperature. The results given in the table are expressed in terms of milligrams of moisture vapour passing through an area of 1 sq. in. of the film under these conditions.

The measurement of viscosity is a matter of great importance in many plastics activities. The viscosity of solutions is accepted as giving a measure of the chain length or degree of polymerization of many polymers.

Apart from this the flow characteristics of the actual solutions are extremely important since so many plastics operations are conducted with such solutions. Examples include the casting of films, the coating of fabrics, the spreading of adhesives and so on. A number of methods are employed, some very accurate and able to give absolute viscosities; others design to give relative viscosities. Some methods are designed for rapid control testing under works conditions.

Ostwald Viscometer

The leading method for determining viscosity is based on the Ostwald viscometer. This is shown in the figure and consists of two bulbs connected by a capillary tube. Marks are etched above and below the first bulb. The other bulb is filled with the material to be tested. This is drawn into the other part of the apparatus until the liquid surface is above the upper mark. The time required for the solution level to fall to the lower mark is noted. The times taken for different liquids give a measure of the relative viscosities. Absolute viscosity in centipoises is found from this by taking the time required for a liquid of known viscosity. When this is known the viscosity is given by $\frac{n}{n_o} = \frac{td}{t_o d_o}$ where n is the desired viscosity, n_o = viscosity of standard, t and t_o respective times of flow, and d and d_o the respective densities.

Experiments must be carried out at constant temperature, since temperature has a profound effect on the viscosity.

Falling-ball Method

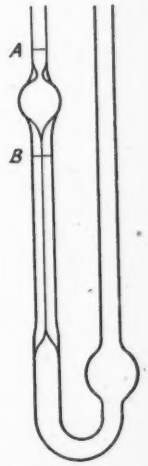


Fig. 14.—Ostwald viscometer.

Methods for determining viscosity have been established by the British Standards Institution. In B.S.S. 188/1937 they describe the Ostwald type of viscometer and the falling-ball method and lay down prescribed conditions. Viscosity measurements must always be made under conditions of constant temperature.

The falling-ball method is extremely convenient, involving simple equipment. Steel balls of specified dimensions are allowed to fall through the solution under test, and the time taken between two marks is measured. They are readily available as standard steel balls used for ball bearings. Obviously the method only applies to clear solutions.

The limits recommended in B.S.S. 188 are as follow:—

Table 17.

Range of viscosity in centistokes	Diameter of ball	
	mm.	in.
1,000 to 5,000	1.59	$\frac{1}{16}$
5,000 to 12,500	2.38	$\frac{3}{32}$
12,500 to 25,000	3.18	$\frac{1}{8}$

The tube must be at least 10 times the diameter of the ball to be used.

A tube 32 mm. in diameter is suitable for the sizes of sphere specified above. The standard distance over which the fall of the sphere is timed is 150 mm., two reference marks this distance apart being provided on the tube as shown (a, b). The length of the tube is such that the reference marks are approximately equidistant from the two ends of the tube, this distance from the ends being not

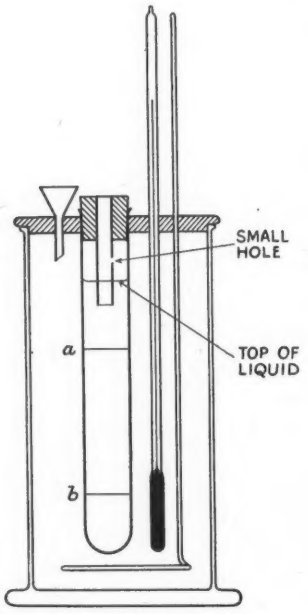


Fig. 15—Standard falling-sphere viscometer.

less than 55 mm. in either case. The liquid is allowed to stand until it is free from bubbles.

The time taken for the ball to fall between the two marks is measured by an accurate stop-watch; several readings are taken.

Gibson and Jacobs recommend the use of pure glycerine S.G. 1.2589 at 20 degrees C. as a standard for the falling-ball method, having a visibility of 10.24 in absolute units.

Hercules Falling-sphere Method

The Hercules falling-sphere method used in America employs the following solution:—

	Per cent.
Dry nitrocellulose	12.2
Denatured alcohol	22
Ethyl acetate	17.5
90 degrees benzole	48.3

The solution is placed in a 1-in. glass tube, and the time taken for a $\frac{5}{16}$-in. steel ball (weight 2.046-2.054 gm.) to fall through 10 ins. of the solution is taken as the viscosity of the grade in question, whether $\frac{1}{2}$ sec., 4 secs., etc. There is a mark 2 ins. from top and another 2 ins. from the bottom. One disadvantage of this method is that a very small time has to be measured in the case of low viscosity cottons, and this is surmounted by using more concentrated solutions of these types. Another objection is that the solvents used are liable to vary.

In the case of cellulose acetate a convenient solution is 20 per cent. in 9 parts of acetone and 1 of alcohol.

A rather better method seems to be that of Messrs. Nobel Industries, Ltd., which employs a purer solvent and a $\frac{1}{16}$-in. falling sphere to give easier timing. According to the grade of nitrocotton, 10, 20 or 40 gm. of dry sample are dissolved in 100 c.c. of commercially pure acetone diluted to S.G. 0.810 at 15.5 degrees C. with distilled water. At a temperature of 20 degrees C., if the time of fall is T secs., then absolute viscosity is approximately $\frac{T}{2}$

The Redwood Viscometer

The most popular routine standard viscosity method employs the Redwood viscometer.

The normal viscometer consists of a copper silver cylinder which contains the liquid to be tested. Enough material is used so that an indicator is just covered. The base of the cylinder contains an agate orifice which is closed by a valve attached to a rod. The whole viscometer is jacketed in order to maintain any desired temperature. Beneath the outlet is a narrow-necked flask graduated with a mark representing 50 c.c. To determine the viscosity the valve is opened and the time required for 50 c.c. of material to flow through the orifice into the flask is recorded. It is expressed by the number of seconds taken.

A simple and rapid method for finding the relative viscosity of a solution is to compare the times taken for 25 c.c. to run out of a pipette.

Planned Mould Maintenance Service Aids Economical Production

Part III

By W. M. HALLIDAY

Considering some simple and useful mould design and constructional features which promote increased accuracy, prolonged wear, and correspondingly reduced maintenance oversight or repair activities

IN the previous portions of this article attention has been repeatedly directed towards the fuller realization of the paramount importance which the two closely allied factors of mould design and construction have upon mould operation, duration of working life, and, what chiefly concerns the subject of this article, the degree of maintenance attention required to maintain the mould in efficient working order.

Emphasis was laid upon the desirability of correct mould designs coupled with the use of stable and reliable materials, plus sound workmanship and constructional methods. These are, indeed, some of the most vital pre-requisites for satisfactory mould manufacture and operation, and not only ensure smooth and economical moulding manufacture, but also a freedom from serious mould failures, errors and breakdowns, which, again, will be beneficially reflected in enhanced production runs and the keeping down of costs.

Preceding sections of this article have dealt mainly with the general questions of organizing and recording effectively maintenance activities, but the subject is far from being adequately covered unless some rather more detailed attention is devoted to the various important contributory aspects of mould designs, principles of construction and methods of manufacture. Such factors exert profound influence upon mould operation and life.

It is now proposed to devote this present section to a more detailed consideration of the above-mentioned points, with special attention to the following, as these are likely to prove of greatest interest and, it is hoped, guidance, to those tool engineers charged with maintaining plastic moulds in good operating condition. These points are:—

(a) Selection of mould materials.

(b) General heat treatment.

(c) Mould designs and constructions as affecting maintenance and good working conditions.

The subjects will be dealt with in the above order, and in all instances moulds employed on the compression process only will be dealt with and illustrated. In a succeeding section to be published later it is hoped to treat in a similar manner mould designs and constructions, etc., applicable to the injection process, which latter, by reason of mould functions, method of operation, intricacy, usually larger number of working parts, semi- or fully automatic operation and high operating speeds, possess their own peculiar kind of maintenance difficulties, which deserve individual consideration.

Method of Presentation

Much of what will be written about the matters of material selection and heat treatment, etc., will, of course, be germane to mould manufacture for every moulding process, and it is only on the important aspects of designs, constructions and methods that compression and injection types of moulds will be treated separately.

The main portion of this present article will thus be concentrated upon the consideration of a number of common design forms with illustrations given of certain

undesirable features as they affect maintenance service and workability or durability of the mould, together with illustrations of suggested improved design forms and ways and means of construction calculated to eliminate trouble of the kind mentioned.

Because of the need for space conservation, it is, perhaps, advisable to point out that this adopted method of presentation of each illustrated design will be one which combines a variety of undesirable features depicted on a single illustration. Readers should not, however, conclude from this method of illustration that any mould design thus given has actually been encountered. All the individual instances of unsatisfactory design forms have been met with from time to time, but, happily, not all these shortcomings are perpetrated in a single mould construction.

Selection of Materials and Their Effects on Mould Life

The enormously important and extensive development of the plastics-producing industry and intricate mould manufacture which has occurred during the past few years has brought the inauguration of new tools, processes, methods, and especially new steels and alloy-steels, for more effectively meeting the needs of this expanding industry.

Especially have the mould design and manufacture operations made increasingly heavy demands on the skill and ingenuity of the steel manufacturer, and in the past few years very considerable progress has been made in the evolution of a whole range of steels expressly applicable for the exacting purposes of the plastic mould maker.

In addition, a very substantial volume of technical data covering the physical characteristics, properties, methods of handling, heat treatment, and so on, has now been built up and is available for the use and guidance of the mould designer and engineer.

It scarcely needs pointing out that every mould designer needs to be well conversant with this body of vital information about these new steels, first in order that a wise choice may be made at the outset to obtain the requisite steel for a particular application, and secondly, that the machinist and heat-room operators may be furnished with the most up-to-date and reliable working instructions to obtain the best realization of the inherent qualities of the materials selected.

Indeed, it would be entirely accurate to state that the length and character of mould working life is very materially conditioned by the selection of materials. Where scant consideration is afforded to this subject in the initial design and pre-manufacturing stages of mould development, diminished life and service may result. In addition to this diminution of working efficiency or capacity, there may be a steep increase in the frequency of minor or even serious breakdowns and the consequent need for the skilled attentions of the maintenance engineer in order to effect corrections, adjustments, or replacements.

Speaking from the purely practical standpoint as one having had considerable and intimate contact with this aspect of mould development as well as oversight of mould maintenance services, it is safe to assert that a very substantial proportion of commonly recurring mould faults, errors, defects, and working difficulties entailing the activities of the mould tool maker or repairer, owe their origin to the selection of unsuitable materials, and more often to their incorrect treatment during some stage of the mould manufacture. The obvious corollary to this is that many such problems besetting the mould engineer could have been avoided had there been clearer understanding of the nature and methods of handling the materials chosen.

Many instances could be afforded to illustrate the foregoing point, as they occur from time to time in the experience of every mould manufacturer. Thus a correct grade of steel may be secured, it being carefully annealed, and subsequently machined through all the intermediate stages of its manufacture until

it reaches hardening stages. Here trouble develops in that the finished mould blocks are perhaps subjected to a final heat treatment for case-hardening, only to be returned to the toolroom in an unsatisfactary condition.

They may be found to be badly distorted on essential surfaces; or such surfaces may be patchy in the degree of hardness, leaving soft spots; or, again, the surfaces may be badly scaled and pitted, or even cracked if adjacent sections are thin or slenderly supported. The core may be too brittle, or the case made too hard, and so one could go on enumerating numerous common faults arising out of heat-treatment operations.

Incidentally, all the above-mentioned faults will incur large amounts of additional time and skilled labour in their subsequent correction, which time, etc., will be extra to that normally allotted for the completion of the final finishing-off operations intended for a correctly hardened mould. Unless such corrective measures are conducted and accomplished in a thorough-going manner minor faults may still remain which will conspire towards a more speedy deterioration or failure of the mould on some essential point, which in turn will require costly maintenance attention.

Furthermore, it should be borne in mind that in cases where such undesirable features are allowed to develop, if of appreciable magnitude, it may not always be possible to effect a complete correction in the final finishing stages without creating some serious and irrecoverable departure from the initial accuracy of some important dimension or surface. So that, quite apart from the question of probable increased maintenance expense, careful material selection and handling is necessary to promote economical mould manufacture. Further illustrations of the many aspects of this matter lie outside the scope of this article.

Requirements of Mould Steels

In connection with material selection it will serve as some guidance to mention at least a few of the chief characteristics which any material intended for plastic moulds should possess. These main characteristics are:—

(1) Cleanliness.
(2) Machineability.
(3) Hardenability.
(4) Freedom from distortion.
(5) Resistance to staining.
(6) Durability.
(7) Resistance to wear.

Very briefly let us explain these seven essential features.

Cleanliness

By cleanliness is meant not only a complete freedom from dirt, non-metallic inclusions, or surface skin faults which are readily discernible before machining of the steel, but also an internal soundness, especially in the core sections, whether in the forged block, rolled plate, or bar. Porosity, splits, slag deposits, spongy patches, internal flaws, etc., inevitably give rise to considerable troubles, by reason of spoilt workpieces, and the wastage of time and labour expended upon them.

Furthermore, such defects are always liable to be magnified in extent and importance by subjection to working pressures and temperatures arising either from actual machining operations necessary to make the mould, or when the mould is finally placed in service.

Thus, when specifying mould steels or alloy steels, this point should be well stressed and a grade selected of assured and proved suitability in this respect. Incidentally, in the case of a very expensive mould about which no such hitch could be contemplated, all such selected materials should be subjected to a test for flaws by means of the hot etching process before being accepted and manufacture commenced.

Machineability

Numerous methods are now employed for obtaining the necessary cavity form in the mould, chief of which are by hobbing, or by machining with a cutter, or a combination of both methods. In the case of hobbing, the hardness of the

alloy steel when annealed will determine in a vital manner the ease and extent of penetration of the hobbing tool, as well as the degree of pressure required. Thus a soft steel (when properly annealed) may be easy to hob, entailing moderate pressure, but, when finished, will lack the necessary strength to make a durable tool. Thus the prospective user, when about to make a choice of steels, will have to make a balance between the three factors of final strength, resistance to wear, and machining or hobbing facility.

The feature of good machineability bespeaks, in the case of plastic moulds, the provision of well-finished, clean-cut surfaces. For this reason the free cutting steels are usually unsatisfactory because of tendencies towards torn and rough surfaces which they possess. Good machining qualities can be considerably heightened by correct annealing operations imparted to material before machining commences.

Indifferently machined mould surfaces, etc., may lead to considerable troubles developing after the hardening stages have been passed, such as the formation of tiny cracks originating from a torn machined surface or rough edge. Localized stresses may also be set up as a result of the increased machining pressures imposed on the part, which, in turn, may become the source of undesirable distortion when case-hardening operations have been carried out.

In selecting a mould material, then, this important aspect of machining should receive its due consideration.

Hardenability

As already intimated, very many disadvantageous features may arise during the heat treating of a mould steel, and especially does this occur in respect of the carburizing and quenching stages of the hardening process.

As will be appreciated by all practical engineers, an incorrectly hardened mould will become the precursor of innumerable operating or assembly problems leading to such things as interference with smooth operation of mould blocks, dangers of seizure of moving parts, fracture of mould members due to cracks or other flaws accelerated by hardening, stiff working of mould, reduced speed of output and so on.

Moulds are generally of complicated shapes and contours involving thick and thin sections of material, hence great strains can be set up during heating operations and subsequent quenching, which, again, may cause the appearance of quenching cracks, softness, loss of dimensions, spots, severe scaling and oxidation.

Design can play an important part towards minimizing such difficulties by modifying mould sections in such a manner as to avoid cracking tendencies. Contours should be as regular, well rounded and as smooth as possible, whilst re-entrant angles, recesses or radii should be generously radiused and blended into straight sides.

The chosen steel should be one permitting easy carburization to an adequate depth and the composition of a durable wear-resisting case. It should be remembered, however, that good carburizing may be spoiled by indifferent general heat treatment, and it should be one of the chief objects of the works metallurgist to secure in the final heat treatment those special features of any given grade of material so as to ensure maximum physical properties and good service.

Freedom from Distortion

This is an obviously highly essential feature, but instances could be afforded from the writer's own experiences where moulds have been made up to a sound design, with the display of excellent workmanship, and use of properly heat-treated materials, but which have speedily called for the attentions of the maintenance engineer when once placed in service. Errors in sizes of finished moulding, or difficulties in the way of mould operation have arisen due to the presence of distortion.

Assembly of the finished mould may also be made difficult or even impossible because of this same condition, and much

time and expense may be incurred in making the requisite corrections and adjustments to mould members.

Treatment of Distortion

The practical disadvantages arising from distortion will be readily apparent. If it occurs during the hardening process itself for instance, the mould blocks will not match up closely enough and the lands surrounding the cavity will fail to seal effectively. The dowel holes in the respective mould blocks may be thrown out of alignment, so that they will not match up, and the cavities similarly misaligned. Stripping sleeves, cores, knock-out bars, guide pillars, ejector rods, top plates, etc., may all fail to fit properly, which will consequently entail additional efforts to correct.

As before stated, such corrective measures may be of such an extent or character to incur important deviations from essential moulding sizes or shapes, or purposes, whilst the speed of working the mould may be drastically reduced. Furthermore, it should be borne in mind that once distortion has developed even though it has been corrected, there can be no sure guarantee that it will not recur as a result of continued alterations of high pressure and elevated temperatures to which the mould is subjected under working conditions.

Should distortion arise after the mould has been finished off and placed in operation on the press, as sometimes happens because working pressures cause a release of internal stresses originally created during heat treating, then even more serious maintenance troubles may arise together with loss of production time.

The greatest care should therefore be devoted to the whole question of heat treatment, including annealing, normalizing, carburizing, quenching and tempering. Similar care should be centred on projected design forms to ensure the creation of mould constructions the least prone to give rise to unequal stressing of parts when under heat, in this manner aiding the hardener to reduce, if not avoid entirely, all distortion.

Resistance to Staining

Some plastic materials set up a chemical action when in contact with steel, therefore selected mould steels or alloys should have the ability to withstand permanent, deep or harsh staining of metal surface, otherwise the high polish and lustre will be speedily marred, and such blemishes transferred to the finished moulded product. In addition, the mould material should be able to resist effects of continuous exposure to super-heated steam, moisture, hot lubricating oils, gases and vapours given off during actual moulding operations, or changes in atmospheric conditions, etc., without producing any undesirable surface stains, pitting, or similar skin defects.

In the case of moulds which have to be chromium-plated, the steel should be one capable of resisting the action of acids which may come into contact with material during plating.

Durability

The ability of a mould material to withstand satisfactorily severe working conditions is again an obvious necessity for the plastic mould manufacturer.

This feature will depend in large measure upon the quality of the chosen material, depth and character of the case, strength and toughness of the internal core, and the general heat treatment afforded to the mould in order to secure such features in permanent form.

In selecting a mould steel, and in especial reference to this factor of durability, attention will have to be paid to the degree of severity of the stresses which are likely to be imposed upon the mould in service, as this factor will condition to a large extent what is required of the core in the shape of mechanical strength, and its structural features.

When relatively small stresses are foreshadowed the case and internal core of material may only have to withstand moderate abrasive action, tendency to indentation, or deformation. But where very great compressive stresses arise the mould will have to withstand a much higher degree of abrasive action, con-

sequently it must have a harder case, and one considerably thicker, whilst the core should possess ample strength to resist all tendencies of the material to " sink " immediately behind the cavities, or from suffering permanent deformation which would cause distortion and misalignment, perhaps, of the mould construction as well as cavities.

The foregoing, then, are undoubtedly exacting requirements, especially so in relation to their use for the manufacture of plastic moulds where they are demanded in combination, but it must be remembered that a mould must have sufficient surface hardness to ensure that the delicate and intricate clear-cut edges of the matrices will be able to withstand abrasive action for substantial periods, so that the moulded article will be maintained in a clean, clear-cut defined nature without variations in sizes and shape.

This, of course, is not the place to enter into a discussion of the processes of heat treatment as applicable to plastic mould steels, since this would necessarily have to be technical to a great degree, and therefore of no great interest to the mould engineer charged with maintaining moulds in good working condition.

Suffice it to mention in conclusion that many different kinds of case carburizing steels, and their methods of heat treatment, are now available to the mould designer, and if the individual requirements of a prospective mould construction are carefully studied in the light of the preceding factors discussed at length, there is no reason why a mould should not result possessing a hard fatigue resisting skin of adequate depth coupled with a high, tough, shock-repelling internal structure which will reduce distortion and abrasive wear to a minimum, and so make for increased working life free from troubles and operating snags.

Preparing the Mould for Hardening

Before leaving this important question of heat treatment, however, there is one aspect of it which is of special concern to the mould engineer because of its effects upon subsequent assembly, operation, and satisfactory working of the mould.

This relates to the preparation of the mould prior to its undergoing heat treatment and hardening. Unless precautions are observed harmful oversights may occur which cannot afterwards be remedied when the mould members have been hardened, or the failure to perform some quite simple task may become the origin of some deleterious cracking, distortion or permanent misalignment.

The steel will have been normalized in the first instance before any machining has been carried out, and in this connection a sound general plan, with high percentage alloy steels containing nickel, manganese and molybdenum, is first to heat the material well beyond its critical stage, say, from 950 C. to 990 C., to give one example of a particular class of alloy steel, then to cool quickly down to about 630 C.-600 C., after which stage the rate of cooling should be slowed down considerably until a temperature of about 260 C. to 230 C. is reached.

This practice will largely force out internal stresses and tendencies to deform, so permitting extensive machining and cutting operations to be performed without the risk of incurring drastic distortion after machining.

For such normalizing operations some manufacturers prefer to perform certain rough machining on the material to remove the bulk of excess material, whilst others elect to carry out the normalizing process directly on the unmachined block.

Where the material is machined prior to normalizing, care must be taken to leave adequate amounts of metal on all important locations to allow for sufficient machining depth and the change of shape which will occur after normalizing.

After the part has been thus normalized and machined up in readiness for the hardening stages it is essential to ensure that all surfaces have been well polished and left entirely free from tooling marks, engraving lines, chatter effects, bruises or scratches, however slight and apparently unimportant these may appear.

Such marks if left in may prove too deep for removal by usual polishing or buffing processes after hardening, and in

addition may become the cause of tiny hair-like cracks or surface flaws which otherwise would not develop.

All sharp corners or knife edges, even those on non-essential exterior surfaces, should be smoothed off or bevelled. Recesses and undercuts or counterboring, as for screw heads, should be smoothly machined up and polished, as a torn surface on the material may prove harmful and troublesome after hardening.

Threaded holes or plain ones of great depth should be well cleaned out of chips, dirt, lubricant accumulations, water, or machining coolants, etc., as these may become the cause of a soft patch in the finished hardened case.

The surface of the matrix, which imparts the surface finish to the moulded article, should, of course, be entirely free from any blemish, and in the case of the cyanide method of case hardening may be finished off exactly to final sizes.

Cleaning Prior to Hardening

Before insertion into the bath, the mould block, etc., should be carefully dried to remove moisture, oil or grease, and should be brushed and air blasted to remove all dirt or dust from the interior surfaces of holes.

With the pack method of hardening this latter operation is not so vital, as the act of embedding the article to be hardened in a powder packed into a hardening pot will of itself serve to remove oil and moisture, etc.

In sum, then, enough has been written for it to be appreciated that very considerable maintenance difficulties may arise from heat-treating operations on the mould members, and the writer, whilst realizing the impracticability of giving comprehensive attention to all the many aspects and important points of interest to the mould engineer and designer, hopes that sufficient has been said to indicate the lines upon which the mould engineer may work in order to eliminate after hardening difficulties, and the economizing in amount of maintenance attention demanded when a mould is finally placed in service.

Compression Moulds. Portable and Fixed Types

Before dealing with the various design and constructional features of the compression-type mould shown in Fig. 1, it will be advisable to mention a few of the more common maintenance snags and difficulties associated with the use and handling of portable moulds. As will be understood, these are generally of a very simple and inexpensive form of construction, and also are not fixedly attached to the press platens, but are inserted between these members for each compression stroke, being afterwards removed for the withdrawal of the finished moulded article.

This handling and movement to and from the press is one which often becomes the means of severe wear being imposed on certain portions of the mould, which in time may lead to a failure of some member and a breakdown demanding the services of the tool repairer.

In order to counteract such adverse effects of handling of the moulds, the unloading table should be as near as possible to the press platen, and also of exactly the same height, unless bridged by a stiff plate at a convenient angle, along which the mould may be slid into the unloading position.

The top surface of the unloading table should be maintained flat, clean and free from bruises, scratches and the like, which if allowed to accumulate might eventually mar the surfaces of the mould which is brought into close contact therewith.

Regular maintenance oversight should be directed to the unloading table and other apparatus to ensure them remaining in sound working order, and of such a kind as to promote the safe handling and transfer of the mould.

The chase and mould blocks should, of course, be amply robust to withstand the repeated sliding to and fro and the dragging about generally. Where a mould is of exceptional weight or bulk as to render difficult easy handling by the operator, some effective means for lifting should be installed, and here again should receive frequent inspection by the maintenance

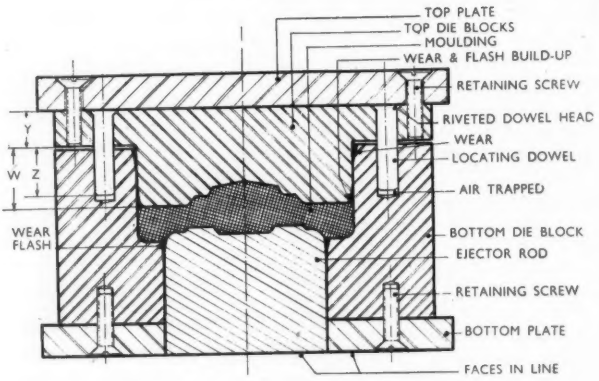


Fig. 1.—Section view of a portable positive mould of simple design possessing certain disadvantages.

engineer to maintain it in sound working state.

It is surprising what a difference a little thought and attention can make in respect of the better organization of the handling and transfer arrangements for dealing with portable moulds generally, and the resultant amount of minor maintenance oversight which may thereby be eliminated.

Of course, each type of portable mould will present its own particular difficulties, and therefore it is not possible to lay down any specific rules to cover every type. But the objective of all such endeavours should be that of maintaining mould accuracy, finish and working life by seeing that it is not subjected to very severe strains and clashing during the transfer from press to table and back again, or that it is not too heavy for an operator to lift unaided by crane, etc., thus running the risk of dropping it.

Also all tools for forcing out ejector rods, levering of top plates, cleaning the mould, etc., should receive regular inspection and test for continued suitability, and adjustments or replacements made from time to time as circumstances demand. Incidentally, each operator

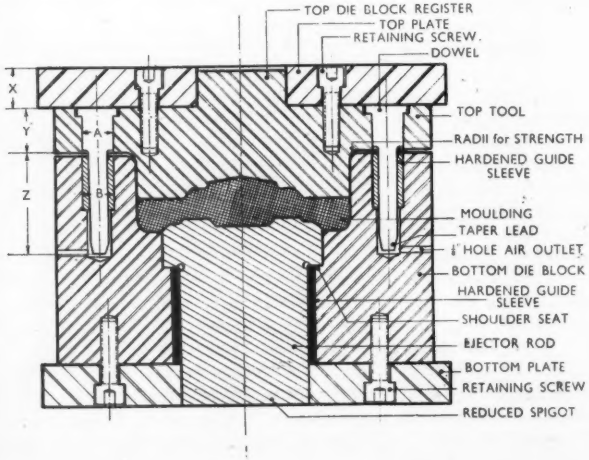


Fig. 2.—A suggested modification of the above to avoid the disadvantages.

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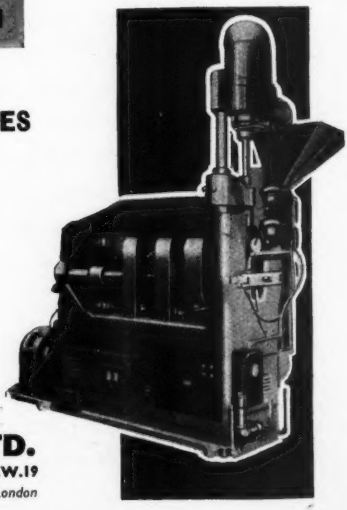

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should be provided with a kit of properly fashioned tools for such purposes and made responsible for their care and good usage. No operator should be allowed to use makeshift tools for the purpose of cleaning the internal cavities of a mould, removing the top plates, or ejector rods, or chase member, etc., as these may be and often are a prolific source of minor damages being inflicted on the mould.

Leaving now the matter of handling of portable moulds, we refer to the illustration in Fig. 1, which is a sectioned view of a fully assembled plastic mould of the portable positive type, which, it will be noted, is of extremely simple design and construction, which, by the way, has been deliberately chosen for the following two reasons.

First, the simplicity of design will serve to enhance the appreciation of the several disadvantageous features which such moulds may unwittingly possess.

Secondly, because of the very simplicity of the design form of such type moulds it is often thought that very little can be done in the way of saving on their maintenance, as there is so little that can possibly go wrong either with their construction or method of operation.

Taking the various undesirable features contained in this construction in turn, we deal first with the:—

Mould Top Plate.—This plate fulfils the important functions of retaining and aligning the entire top half of the mould and serves as a rigid backing for the top die block. Therefore, it is obvious that this plate should have ample stiffness and cross-sectional thickness capable of fully resisting any deflecting or bending tendencies likely to arise as a result of the compressive pressures imposed on the mould.

Cases may arise where it is impossible to have a thick top plate, and if this is coupled with a somewhat thin top die block also, there may be a danger of distortion and flexing of both members occurring when the mould is placed under pressure. Such a feature would entail frequent attentions from the mould maintenance engineer, and would cause harmful wear on the sides of the extension of the top die block and that of the matching recess in the bottom die block, which would allow flashing vertically on the top surface of the moulded article and loss of accuracy.

Top Plate Alignments.—It will be observed that no means is provided for securing the correct and permanent alignment of this top plate to the top die block, apart from that afforded by the countersunk headed screws. No dowels exist for performing this function.

In actual use some care will be needed lest these screws work loose due to some cause, such as the vibration on mould, stretching by variations of temperature, or accidental slackening off by an unauthorized person. Should this feature occur, there will be a danger of unequal compressive forces being imposed on the mould because dirt or excess plastic powder, etc., may become lodged under one end of the top plate between its lower surface and that of the top die block.

Such an occurrence would tend to bend and stress the dowels, causing them to wear at an excessive rate, whilst the guide holes in the bottom die block may suffer similar rapid wear, which, if uncorrected, would lead to serious misalignment of top and bottom tools, with an inaccurate finished product.

It is also essential that the top plate be exactly parallel and have dead flat surfaces top and bottom. This member should receive a periodical inspection and test to ascertain adherence to this condition. In a like manner, the bottom plate should be of sufficient strength to resist distortion, and also made exactly parallel and flat both sides. If this is done there will be greater likelihood of eliminating errors in setting-up when the mould is placed between the parallel press platens.

Dowels

These are very important mould components and serve a number of extremely vital functions on practically every type of mould construction. Where dowels are unsatisfactory, poorly designed, the product of bad workmanship, or indifferently

installed in position, they may become a most fruitful source of trouble for the toolmaker and maintenance engineer.

Because of their importance to sound mould construction it is well worth while enumerating briefly some of their chief beneficial objects, because it is feared in some cases these are apt to be overlooked in preference for the achieving of the single advantage of cost cheapness.

(a) Dowels serve to secure and maintain correct alignments to mould members.

(b) Rubbing and abrasive wearing action is removed by the use of dowels from more vital mould members, thereby promoting accuracy and smooth working.

(c) Replacements are facilitated by reason of the comparative ease with which worn or damaged dowels may be renewed.

(d) Dowels tend to equalize pressure thrusts upon mould die blocks and kindred components, thus assisting smooth operation and increased durability.

(e) They should be of a design capable of very tight fixture into position, and also of such a type as to permit them being secured in place without loss of squareness or straightness in relationship to mould members.

(f) The dowel should be strong enough to resist all bending tendencies, and hard enough to withstand long and severe rubbing with mould members.

In view of these purposes and requirements the type of dowel shown in Fig. 1 must be considered very unsatisfactory. It is a kind in widespread use, however, the reason for such popularity being, possibly, its extreme cheapness. As will be seen, it consists simply of a length of plain cylindrical steel rod (silver steel is usually employed), being made a tight fit in the hole in top die block with one end riveted over to form a small head-like flange filling a countersunk recess machined in top face of block.

This method of fixing is most unsuitable because it is difficult to retain the projecting end of dowel square and true whilst its end is being riveted over. Particularly will this be so if the dowel has to be inserted into a narrow section, or a hole of very short length. Then again it can be very easily pushed out of place, or pulled forward as the peened-over head portion can offer only a slight resistance to such forces. The constant repetition of mould opening and closing imposes great strains upon the dowels, and with this type much trouble may arise because of end-wise shift or loosening of the piece.

Another unsatisfactory feature to be observed in connection with this form of dowel is its lack of length (Z). This will mean that when the two respective die blocks are closed in readiness for compression cycle they will first be aligned not by the dowels at all, but by means of the centre extension piece in top die block which engages the upper end of cavity recess in bottom block. This will result in rapid and heavy wear taking place at the points illustrated by heavy black shading on top and bottom die blocks, which, in the case of the former tool, will cause an alteration in the shape of the mould cavity proper and a consequent departure from original shape of the moulded article. To obviate this the dowels should be much longer than distance W, so that they engage the guide holes in bottom block well in advance of any other portions of top block contacting the mating member.

Still another important drawback to be noted is that insufficient lead taper or radius is provided on the extreme forward tip. Absence of this is apt to make for harsh engagement and rough operation of the mould blocks, whilst the dowel end may receive a slight mushrooming effect which in time will make opening or closing of the blocks difficult.

Finally, the holes in bottom die block into which the dowels are inserted are drilled too shallow, thus leaving but a small space between bottom of hole and end of dowel when blocks are closed. Air will be trapped in this small space which may make operation stiffer.

Ejector Rod

Another possible source of trouble for the maintenance engineer in this same construction in Fig. 1 relates to the

ejector rod member located in bottom die block. As this is a portable mould this member will have to be knocked out of die block in order to secure withdrawal of the finished moulding. This action will in time entail some wear on the sides of hole in die block, which will then become the cause of increased flash formation at the points heavily shaded. In addition, the ejector rod itself will suffer some wear, especially at its foremost end, which has to fit flush with bottom of cavity formed in bottom die block. Once the sharp leading edge of rod is worn away a space will develop in which a flash may form.

Some maintenance attention will therefore be required to correct such tendencies, and the remedies will mean somewhat serious and costly operations. In the first place, the bottom die block will have to be stripped, set-up true in the cylindrical grinding machine concentric with its central bore, and then this hole ground out slightly larger, sufficient to remove all signs of wear. This accomplished, a new ejector rod will have to be made up also slightly bigger in outside diameter to suit the enlarged hole. One danger in this corrective operation is that enlargement of hole in die block may involve the removal of the hard case of material, in which the hole may have to be opened considerably larger and fitted with a reducing sleeve having a bore of original size.

Yet another disadvantage is to be noticed respecting this simple type of ejector rod. It concerns the method of obtaining the correct vertical location in relationship to bottom die block cavity. When the mould is being reassembled prior to placing under the press, the ejector rod will have to be cleaned and inserted by hand into its proper position. Its exact location will be determined by position of its end face, which should lie exactly flush with the lower edge of the bottom plate, as shown.

This means is open to several objections. It is far from being positive. Thus if dirt accumulates on the top face of press platen, and the operator overlooks its removal, it may cause the ejector rod to be raised slightly when mould blocks are resting on platen. This will result in a moulded article with a too thin central web and a too deep bottom recess. Again, if bruises or foreign material particles become attached to the lower edge of the bottom plate when placed on the press platen, these may allow the ejector rod to fall downwards a small amount, which will result in a moulding having its central web too thick and bottom recess portion made too shallow.

Location of Top and Bottom Plates to Press Platens

One further final point deserves attention. This refers to the method of aligning the top and bottom plates to the press platens. It will be advisable in the case of lightweight moulds, capable of being easily lifted by an operator, to provide a reliable form of dowelling each plate to its respective press platen. This will ensure that the mould is always located at the same point. This will avoid errors and unequal compression forces being transferred to the mould itself if the press platens themselves should wear and thus become slightly out of line of parallelism.

In the case of very heavy moulds which cannot be lifted with convenience, instead of dowel-type locators, strips of material may be secured to the platen against which the mould may be moved to secure location. Such strips will, of course, only contact two sides of the mould, preferably two sides situated 90 degrees apart, thereby permitting the mould to be drawn away readily on to the unloading stand without interference.

If this is done considerable assistance will be afforded the maintenance engineer. The mould will always be located centrally on the press, with the ram contacting top plate centrally; thus uniform pressures will result, which will materially assist in preventing distortion and damage to mould members.

Turning now to the similarly sectioned view of the same mould in Fig. 2, various

improved forms of construction are illustrated for overcoming the foregoing troubles in a simple and inexpensive manner. The respective objectionable features arising out of the design in Fig. 1 will be dealt with in the same order as previously discussed.

Top-plate Alignment

It was suggested that this member be preferably located positively to the top die block by means of substantial dowels, and whilst this is undoubtedly a simple and useful means of attachment, in Fig. 2 is shown another equally effective and inexpensive way which can be adopted on numerous designs.

The top die block is formed with a cylindrical register or spigot on its uppermost face, located centrally with the lower extended piece engaging the mould cavity. The top plate is bored out suitably to be a smart press-on fit over this spigot, in which way the two members become very positively aligned. This kind of register will, of course, be found much stronger than that afforded by dowels, and in the case of large moulds or those subjected to varying side or angular pressures will certainly be more reliable than dowels.

Fixing Screws

Instead of the ordinary type of countersunk head screw before employed, the top plate is suitably counter-bored to receive the head portion of socket-head cap screws. These are usually of toughened alloy steel, heat treated, and will be found in practice to afford a much more powerful lock, as a small wrench has to be employed for turning them, in contrast to the use of the ordinary screwdriver, which is required for turning countersunk screws.

The top plate is also somewhat thicker, as shown at X, this affording stiffer and more rigid back support to the thinned end webs of the top die block, as at Y.

Of course, in the type of mould here depicted this is not of vital concern, because the material thickness covered by distances X and Y together make an amply strong support for any possible pressures which will be imposed on the mould.

The bottom plate is also similarly affixed by socket-head cap screws.

Dowels

In the same illustration is shown what the writer feels is perhaps one of the most serviceable and reliable forms of dowel for use on plastic moulds, especially as main dowels for aligning die block members. This comprises a toughened steel dowel suitably case hardened, and made of two different diameters. The large diametered portion is made a very tight driving fit within a plain bored hole in top die block, and a shallow recess is provided in top face of block to house the head portion left on dowel, as indicated.

The bottom die block is provided with a drilled hole in line with that housing dowel in upper block, which hole is then fitted with a hardened and ground or lapped sleeve driven tightly into position. Into the lapped bore of this sleeve the plain cylindrical portion of dowel is made a snug, sliding fit. The hole in top die block taking the dowel is made the same diameter, as at (a), as that in bottom block for receiving the sleeve indicated at (b). This facilitates machining. The hole in bottom block is only drilled this diameter for the length of the sleeve, the remaining bottom portion being made smaller in size, as shown. This provides a small step, against which the hardened sleeve can be driven, in which manner the latter part is prevented from being pushed too deeply into the hole. Incidentally, the writer generally makes the sleeve length not less than three times the diameter of smallest end of the dowel being fitted.

This dowel design is extremely satisfactory in practice, and can be guaranteed to give years of trouble-free service, providing due care and reasonably sound workmanship are displayed. The large diametered end, which fits the top die block, ensures increased accuracy and squareness of the dowel fixture, whilst the head prevents any tendency to pull out when die blocks are being opened. Move-

ment in an opposite direction is prevented by the presence of the top plate immediately above dowel head.

Attention is also called to the lead formed on forward end of this dowel. The writer favours this shape of lead rather than a 45 degrees bevel or semi-spherical shape. The side angle of this lead is made approximately 20 degrees, and the lead extends in length for at least a distance equal to dowel diameter. The dowels also are made to extend an ample distance (Z) from underside of the top die block, so that they make full engagement with bottom block before the important central portions of both blocks make contact with one another. In addition, small air outlet holes are drilled through the sides of bottom block, and passing clean into bottom of the dowel holes, as shown.

From the maintenance point of view, should this form of dowel wear it can easily be extracted and replaced. Similarly, should the bore of the hardened sleeve wear, this member, too, can be speedily withdrawn and replaced, so that the initial alignment is at once re-secured. This is in striking contrast with the replacement of the type of dowel illustrated in Fig. 1, where the worn hole in the bottom die block presumably would have to be ground or otherwise machined to a larger diameter, and either a sleeve fitted or a larger stepped dowel made up.

By this means, then, the risks of wear and consequent flash formation at the points indicated in Fig. 1 will also be mainly avoided, even though the mould be subject to very rough and unskilled handling during reassembly stages. Essential sizes and correct alignments of mould members will, therefore, be prolonged, and reduced attention demanded from the tool engineer.

This question of dowels is one of the utmost importance, and where portable moulds are concerned the dangers of troubles arising therefrom are, perhaps, greater than in the case of fixed-type moulds, which latter are located accurately and permanently upon the press platens throughout a complete production run, and, moreover, are opened and closed with the even, smooth movement of the press ram, but which means it is possible to arrange for a very uniform equalized pressure to be directed on the moulds, and in particular upon the dowels, so that one dowel is not subjected to more drag or side thrust than the others.

Ejector Rod

The possible troubles outlined in reference to the first construction shown in Fig. 1 are to a great extent eliminated by employing a design of the kind shown in Fig. 2. Here it will be noted that the ejector rod is made of two concentric diameters, the larger one fitting so as to slide smartly within the bore of the bottom die block. On this enlarged end portion the underside recess shape of cavity is formed. The remaining portion is reduced in diameter, and, of course, fits in a similar degree of closeness within the smaller diametered hole in both die block and bottom plate. This hole in block, it will be seen, is bushed by means of a hardened steel sleeve, which may be ground and lapped if desired to obtain a very smooth yet close fit. When the rod is in correct vertical position relative to the mould cavity, its uppermost shoulder rests upon the step formed at junction of two diameters in the hole, thereby being positively positioned relative to cavity, and quite regardless of the position of its end face respecting bottom edge of plate.

The advantages of this method are several. First, the hardened sleeve affords ample guidance and long life to die block. Secondly, as the bulk of the ejector rod is fitted within this sleeve, little wearing or abrasive action is directed to the vital upper end portion forming the cavity. When assembling the ejector rod the reduced shank portion must be engaged first, which ensures that the rod is correctly aligned well before its upper shoulder contacts the cavity part. Thirdly, should wear occur the sleeve is easily renewable, and can be very quickly changed for a new sleeve without incurring any machining or alteration of the die block as is involved with the previous construction. Fourthly, location is posi-

tive and largely free from interference by burrs, foreign materials, etc.

In passing, another very useful and time-saving feature worthy of consideration is that by providing such bearing sleeves, or bushings for dowels and ejector rods and the like, the maintenance engineer will be better able to anticipate possible points of wear and the extent to which it has occurred, as well as being enabled to lay by a stock of such sleeves, etc., for replacement purposes against the time of their need. Where such parts are not provided with bushes, etc., he will be compelled to make an examination to assess the wear and from that only will he be able to decide corrective steps.

This latter maintenance factor applies, of course, to all designs of moulds and not simply to those being discussed at this juncture, viz., portable moulds.

(To be continued)

Resin-treated Wood Products

The U.S. Office of War Information gives the following details of plastic-treated woods that have been developed by the Forest Products Laboratory:—

Under war conditions wood technology in the United States is coming of age, and a report from the U.S. Department of Agriculture describes a recent group of new products that have been developed at the Forest Products Laboratory. These products are known as impreg, compreg, hydroxylin, papreg, and uralloy.

Uralloy is the name for a group of products, including several already being developed commercially. Little can be said about them now, except that three government patents covering their development have been obtained.

Impreg is a product made up of sheets of veneer. They are impregnated with a water solution of phenolic resin-forming chemicals, dried and cured so the resins act within the wood, and are then bonded together with resin glues and heat. Impreg looks like wood, has much higher resistance to swelling and shrinkage caused by variations in moisture conditions, as well as to decay, surface checking and weather chemical action and electrical conduction. Impreg lacks the toughness that is required for many war purposes, and consequently its use thus far has been limited. Its greatest future lies in facing for ordinary resin-bonded plywood for external use, such as siding. Its advantage for such use is that it largely prevents face checking and raising of the grain. It also furnishes high resistance to decay and to termites.

Compreg, also made up of sheets of veneer, receives the same treatment as impreg up to the curing stage, when hot pressing at different pressures is used. Moderate pressures can compress the material from a third to a half. The product gets a highly polished, hard surface, that resists water, alcohol and mild acids.

Used now for aircraft propellers, radio attennæ masts, bearing plates for various types of fastenings, and jigs for fabrication of aeroplane parts—its durability, strength and ease of maintenance should make it especially valuable for such products as fine furniture, tables, bar tops and flooring if quantity production lowers cost.

Hydroxylin is a low-cost, general-purpose plastic made from mill run sawdust, preferably from hardwoods. The wood is hydrolysed with weak acid or aniline to convert part of the cellulose to sugars, which are removed by washing. The residue is dried, powdered and mixed with smaller quantities of resins than are normally used with wood flour for making conventional thermosetting moulding plastics. It can also be made into laminating sheets.

In finished form the material is glossy black, has high electrical resistance and can be cut with machine tools. It bonds well with brass, bronze, aluminium. Because of its good strength and high acid resistance, it is being considered to replace hard rubber for battery boxes.

Papreg, made of resin impregnated layers of paper pressed together, is not the first product of this kind, but up to now is the strongest. Equalling aluminium in tensile strength on a weight basis, it is being produced experimentally for aircraft wing ribs, wing tip skims, and control surfaces, and is considered for use in water craft, from small vessels and cargo carriers to flying-boats.

Uralloy is described as urea-plasticized wood. When treated with resin-forming chemicals it become a flexible wood. Made by compressing urea-impregnated wood under heavy pressure, it is known as uralloy **B**.

BRITISH PATENT ABSTRACTS

560,475. Application: 7.10.42. **Method of and Means for Producing Moulds of Plastic Material.** R. Pollak.

A method of producing mouldings of plastic materials in which fibres are moulded into a blank form to the shape of the article to be produced and plastic binding material applied thereto, followed by application of a curing and/or pressing process. The dies in which the blank are placed may be of thin sheet metal to which balanced fluid pressure is applied.

560,660. Application: 27.1.42. **Improvements in and Relating to the Production and Treatment of Vinyl Compounds.** American Viscose Corporation.

A process for the manufacture of synthetic resins and particularly filaments and fibres consisting in dissolving or dispersing a co-polymer of vinyl chloride and vinyl acetate, the molecular weight being at least 15,000 and containing 80 to 90 per cent. of vinyl chloride. The solution is subjected to the action of chlorine until the total chlorine of 50/58 per cent. by weight is obtained. Improved solubility and a shrinkage temperature range above 100 degrees C. are claimed.

560,663. Application: 29.4.42. **Polymeric Materials.** E. I. Du Pont de Nemours and Co.

A process for the production of polymers which comprises heating in the presence of a metallic drier an ester of an unsaturated polycarboxylic acid and an aliphatic unsaturated monohydric alcohol in which alcohol the carbinol group is attached only to a saturated carbon atom.

560,665. Application: 22.5.42. **Improvements in Processes for the Production of Vinyl Esters of Organic Acids.** Mo Och Domsjo Aktiebolag, Ornskoldsvik, Sweden.

A process for the production of vinyl esters by the addition of a carboxylic acid or its derivatives containing a free carboxylic group to an acetylene hydrocarbon in the presence of a catalyst, characterized in that the reaction is carried out in the presence of a fluorine compound containing an element of any of the Groups IV-VI in the periodic system.

560,753. Application: 26.8.42. **Volume Stabilized Acid Absorbing Resin.** The Resinous Products and Chemical Co.

Resins having a capacity for absorbing acidic constituents from fluids and having a reduced tendency to swell are prepared by reacting 90 to 60 parts of a condensate of a methylol-forming phenol, formaldehyde and a non-aromatic amine with 10 to 40 parts of a carbohydrate which will reduce Fehling's solution or yield reducing substances when heated in alkaline solution, the resulting product made insoluble by heating it between 75 and 135 degrees C.

560,748. Application: 5.3.42. **Improvements in or Relating to the Plasticizing of Amino - aldehyde Resins.** British Industrial Plastics, Ltd.

A resinous amino-aldehyde condensation product may be plasticized with di or trihydric alcohol or esters which are obtained by polyene fatty acid or ester and hydrogenating the polymer to the corresponding alcohol.

560,808. Application: 24.6.42. **Improvements in or Relating to Adhesive Compositions.** B.B. Chemical Co., Ltd.

An adhesive composition is made from (a) a co-polymer or butadiene and acrylonitrile, (b) an organic solvent, and (c) a substantial proportion of a resinous toughening agent such as a chlorinated rubber or vinyl resin.

560,693. Application: 4.9.42. **Improvements in or Relating to Urea Formaldehyde Condensation Products.** Leicester, Lovell and Co., Ltd., and Harold Arthur Collinson.

A liquid non-crazing composition comprising an aqueous solution or dispersion of a synthetic resin of the urea-formaldehyde type to which has been added furfuraldehyde.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

PRODUCTION BULLETIN. The June issue of "Production and Engineer" contains several special articles of importance. In this issue is the first of a series entitled "Production Control in Practice," which describes in simple terms the principal features of the system adopted for controlling production in a firm's works. The system described is based on the application of certain broad principles, which govern efficient production control in factories both large and small. Another interesting article is that entitled "Improved Wood," which describes in particular the production of resin-bonded veneers for aircraft propeller and press tool manufacture.

PLYWOOD TUBING. A plywood tubing known as "Plytube," fabricated from thin veneers and thermosetting synthetic resin, is reported to have been developed by the Plymouth Corporation. It has a specific gravity of considerably less than 1.0.

THE COLLAPSIBLE TUBE MANUFACTURERS ASSOCIATION has now been reorganized and incorporates the leading manufacturers of the country. Members will co-operate with a view to attaining a high standard of manufacturing efficiency and to giving the best possible service to all tube users. Advice or technical information required by tube users will be freely given by individual members or by the Association's Technical Committee.

The secretary of the Association is Mr. W. E. Fitzhugh, and the address is:—Collapsible Tube Manufacturers Association, National Bank House, 101, Baker Street, London, W.1. Telephone: Wel. 1727.

VAB PRODUCTS contemplate a marked extension in its activities, which now include precision engineering, electro-plating, plastic mouldings, curtain rails, buttons, lenses and reflectors. British Buttons Industries Co. is a subsidiary of the company.

TECHNICAL COURSE. As a preliminary step to the starting of a course on plastics at the County Technical College, Wednesbury, a lecture was given at the college recently by Mr. L. A. White, technical service engineer of Bakelite, Ltd., illustrated by a film, "The Material of Infinite Uses," showing various forms of plastics in manufacture and use.

"PLASTICS," U.S.A.—A new journal entitled "Plastics" makes its appearance in the United States of America, and we hasten to congratulate the publishers and editors of the excellent production. The design is typically American, prolifically illustrated and often in three-colour work, and contains many important contributions from well-known workers in the plastics field. We note that our old friend E. F. Lougee, of the Plastics Institute, contributes the leading article entitled "Wartime Developments of Plastic Materials."

A long life and a prosperous one!

THE WILLIAM H. NICHOLS MEDAL for 1944 of the New York Section of the American Chemical Society has been presented to Prof. Carl Shipp Marvel for outstanding contributions to knowledge of the structure of vinyl polymers, the long-chain molecules used as rubber substitutes, in production of plastics, and as thickening and blending agents in chemical manufacturing, and for his research in the structure of sulphur dioxide—olefin polymers. Prof. Marvel is professor of organic chemistry at the University of Illinois, and president-elect of the American Chemical Society.

MR. ARTHUR E. SKAN has joined the board of directors of George Ellison, Ltd., and of Tufnol, Ltd.

MR. HENRY ROCHESTER has retired after 23 years' service with the Metropolitan-Vickers Electrical Co., Manchester. After 20 years with Dick Kerr and Co., Preston, Mr. Rochester resigned his post as designing engineer to join the staff of the Plant Engineering Department of the Metropolitan Vickers Co., and in latter years has become an expert on insulation problems and the use of "Bakelite" materials for special purposes, especially of late, to design and application of "Bakelite" water-cooled bearings.

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The cloth of various kinds which comes into our factory will never see a laundry. We treat it with synthetic resin and sheets of it are bonded together under heat and pressure to make the Paxolin from which quiet, smooth-running gear wheels are made. Paxolin, of course, is made in different grades from a variety of treated materials ranging from paper to woven asbestos, and because it is strong and easily machined has a great number of electrical and mechanical applications. We're always ready to set the wheels moving in response to an enquiry as to the suitability of Paxolin for any particular purpose.

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Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XXIII.—Coating Media on Vinyl Acetate and Polyvinyl Alcohol Base (Contd.)

POLYVINYL acetals can be produced by two methods: (a) either from polyvinyl acetate as a starting material by means of simultaneous saponification and acetylation, or (b) direct from polyvinyl alcohol. The latter, in turn, can be derived by saponification of polyvinyl acetate in alkali or acid media. In the first case polyvinyl alcohols contaminated with salts which are difficult to remove are obtained. The products derived by the second method from acid media are purer; ethyl acetate is produced as a by-product.

The second method of producing acetal requires a supplementary operation for synthesis of polyvinyl alcohol and is more cumbersome. Ushakoff and co-workers[373] have subjected the method of simultaneous saponification and acetalysing by means of acetaldehyde to an extensive study. According to this method the reaction is conducted in alcohol solution in the presence of acid catalytic agents (e.g., H_2SO_4, H_3PO_4, HCl, $ZnCl_2$, etc.). Depending on the ratio of the reagents and the operating conditions under which the process is carried out, acetals of various degrees of replacement may be obtained, the relative quantities of

$CH_3-CH<^{O-}_{O-}$, CH_3CO and OH— groups

varying within very wide limits. Taking into consideration the fact that polyvinyl acetate employed in the reaction may be of varying molecular weight, it is easy to see that the diversity of possible types of acetal resins derivable by this method can be very large—from the water soluble type to the grade soluble in hydrocarbons, with respective variations of their physical and chemical characteristics.

The tentative experiments conducted by Ushakoff and his associates at the Leningrad Plastics Research Institute were set up to study factors controlling saponification of polyvinyl acetate. For this purpose a 25 per cent. alcoholic solution of polyvinyl acetate, containing 1 per cent. of sulphuric acid as catalyst, was heated to boiling, and periodically, at intervals of three, five, eight and ten hours, samples were taken and diluted with water; in all these cases precipitation of the water insoluble portion of the reaction sample was observed. Preliminary experiments on the production of polyvinyl alcohol by alkali saponification of the acetate have demonstrated that the polymer under these conditions is water soluble.

To clarify the question in regard to the course of the saponification process a series of special experiments were set up, with control of the amounts of ethyl acetate and acetic acid formed during the saponification:

$$-CH_2-\underset{|}{\overset{OCOCH_3}{CH}}\left[CH_2-\underset{|}{\overset{OCOCH_3}{CH}}\right]_n-CH_2-\underset{|}{\overset{OCOCH_3}{CH}}- + mC_2H_5OH + H_2O \rightarrow$$

$$\rightarrow CH_2-\underset{|}{\overset{OH}{CH}}-\left[CH_2-\underset{|}{\overset{OH}{CH}}\right]_n-CH_2-\underset{|}{\overset{OH}{CH}}- + CH_3COOC_2H_5 + CH_3COOH$$

Table 12.

Ratio of aldehyde to polyvinyl acetate, mols.	Percentage of hydrochloric acid	Properties of acetal							
		Temperature of fusion, °C.	Viscosity, centipoises	Flow, by Raschig test, mm.	Water absorption, per cent.	Hardness		OH	$COCH_3$
						By Shore test	By Brinell test		
1.2	2.2	160	—	—	2.5	—	—	—	—
2	2.0	158	228.4	20	0.96	—	—	4.37	1.76
4	1.9	158	98.8	27	0.64	71	20.6	—	—
8	2.0	159	41.9	82	0.69	72	32.6	3.06	2.9

With this object in view test samples from the reaction mixture were titrated with 0.1 normal NaOH. The ethyl acetate was then distilled off in a Freidenberger apparatus in the presence of periodically added alcohol. The quantitative data obtained during one of the saponifying experiments, using 1 per cent. sulphuric, are given below:

Duration of the process (in hours)	1.5	9	16
Percentage of saponification of polyvinyl acetate ..	16.3	45.0	75.8

After 19 hours polyvinyl alcohol was precipitated.

The resultant precipitates are soluble in water and are reprecipitated from the latter on addition of excess of alcohol, which corresponds with the behaviour of polyvinyl alcohol obtained by saponification in presence of an alkali.

In view of the long duration of the saponifying reaction, the quantity of catalyst has been increased to 2 per cent. In subsequent experiments the medium employed was hydrochloric acid. A few of the experiments showed that, under these conditions, release of the precipitate is observed after three hours. In one experiment the precipitate of polyvinyl alcohol, filtered after four hours' heating and air dried, showed a degree of saponification in the neighbourhood of 92 per cent., as against 99 per cent. theoretically possible.

Further experiments have been arranged on the basis of conjoint saponifying and acetalysing processes. Since, on addition of acetaldehyde to the alcohol-water solution containing hydrochloric acid, the aldehyde will polymerize, it has been found preferable to work with the more convenient paraldehyde. The experiments were carried out in the following manner:—To the alcoholic solution of polyvinyl acetate was added an alcoholic solution of hydrochloric acid and of alcohol in such a proportion that the resultant concentration of polyvinyl acetate solution was 25 per cent., with the HCl content at 2 per cent. by weight of the total reaction mixture. After this paraldehyde was added and then determinations of the acidity were made. Subsequently the reaction was conducted at boiling temperature for 10 hours.

On completing the process the acidity of the reaction mixture and the percentage of ethyl acetate were also estimated. The derivation of acetal in chemically pure state is difficult, as the acetal precipitate settling down from the viscous solution contains electrolytes, the removal of which by mere washing is hardly feasible. For the purpose of purifying acetal products there have been suggested various methods. Thus, for example, one may[374]

Table 13.

Viscosity of 8.6 per cent. toluol solution of polyvinyl acetate	Properties of acetal				
	Viscosity, centipoises	Flow, by Raschig test	Water absorption, per cent.	Hardness	
				Shore	Brinell
3.18	31.6	65	0.66	71	21.6
8.4	254	20	0.8	71	21.6

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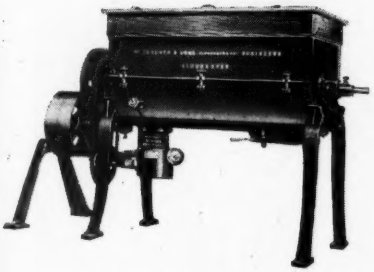

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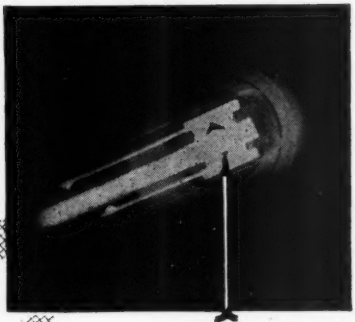

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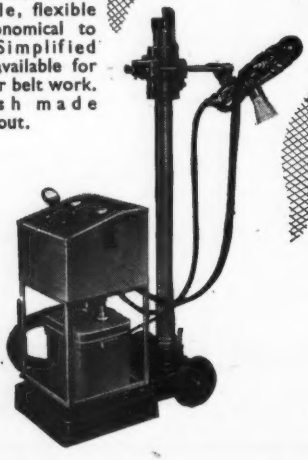

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Table 14.

Polyvinyl acetate, Mols.	Ethyl acetate, Mols.	Alcohol, Mols.	Paraldehyde, Mols.	Properties of acetal						
				Fusion temperature, °C.	Viscosity, centipoises	Flow, by Raschig test	Water absorption, per cent.	Hardness		$COCH_3$ per cent.
								Shore	Brinell	
1	1	1	2	135	11.6	188	0.73	70	21.6	—
1	1	2	2	149	12.3	188	—	—	—	—

dissolve acetal by application of liquids, which at normal temperature assume the gaseous state (viz., ethyl chloride and methyl chloride, ethylene oxide, dimethyl ether, sulphur dioxide and others). The acetal solution is released from the reaction chamber into water or other non-solvent, whereby the acetal is thrown down in the form of a porous precipitate easily amenable to washing.

By preliminary experiments, Ushakoff and his co-workers established that acetal can be liberated from the reaction mixture by pouring into water. However, in order to obtain a product capable of being filtered and with better prospects for washing out of the alcohol, it is necessary to dilute the reaction mass with at least three volumes of alcohol, for otherwise there occurs the formation of "balls" with acetal envelopes entrapping the solution of polyvinyl acetate.

To neutralize mineral acid, sodium bicarbonate in excess of that required by calculation is added to the water. The mass resulting from precipitation, which can be well filtered after washing with water, was compressed, comminuted and dried in vacuo at 98-100 degrees C.

The method of preparation described for the acetals ensures the obtaining of products free from electrolytes, but, notwithstanding its convenience, cannot be recommended for industrial practice, as it involves a considerable expenditure of alcohol, and this appreciably increases cost of production. Supplementary experiments, however, have showed that there is a possibility of producing chemically pure acetal without dilution of the reaction mass with alcohol, and offering possibilities of reclaiming volatile solvents contained in the reaction mixture.

For this purpose, to the reaction mass, on the completion of the process, is added sodium bicarbonate and a large quantity of common salt. The volatile components of the reaction mixture are then evaporated. Under industrial conditions the components distilled off from the mixture can, naturally, be recovered. As evaporation proceeds, the mass, passing through a dough-like stage, balls up on stirring, and after short drying can easily be crushed.

The powder so obtained is repeatedly washed by decantation and then filtered to remove sodium chloride, and finally dried in vacuo at 98 to 100 degrees C. The final product contains no acids or other mineral matter.

In carrying out this work Ushakoff and his collaborators employed either one or another method of washing. The first, on account of low mechanical losses, affords a better means for determining the yield; however, for production on an industrial scale only the latter method of purification can be recommended.

Acetalysation

The same investigators have performed a series of critical experiments on the acetalysing reactions at various ratios of acetaldehyde to polyvinyl acetates. On the samples of acetals thus obtained, determinations were made of the viscosity of 8.6 per cent. solutions in toluol, the ability to flow in the Ruschig's moulding press at 170 degrees C., and a pressure of 150 kgs./cm.^{2} held for 55 seconds, the hardness by Brinell and Shore tests and water absorption by means of discs 33 mm. in diameter and weighing 2.5 gms. Experimental results are presented in Table 12.

The viscosity obtained in one experiment was not estimated, as the acetal formed is insoluble in toluol. This circumstance, as well as a large water absorption, indicates a small degree of aldehyde replacement.

Even with a molar ratio of acetaldehyde to polyvinyl acetate equal to two, the degree of the replacement reaches from 70 per cent. to 80 per cent., which is characteristic of the products of the Shawinigan Chemicals, Ltd. However, the flow factor of samples, even with considerable increase in aldehyde content, is clearly too low. Experiments on drying in vacuo at 50 degrees, 70 degrees and 100 degrees C. revealed that the drying temperature exerts no influence on the flow properties of the test specimens.

As is seen from Table 12, flow and viscosity are interconnected; the lower the viscosity the higher the flow. With the object of studying the influence of the viscosity of the initial polyvinyl acetate upon the properties of acetal, experiments on acetalysing of low viscosity polyvinyl acetates were conducted. A special grade of polyvinyl acetate was prepared according to the method of Ushakoff and Fainstein. Table 13 gives test results and compares the properties of two specimens of acetal resins, obtained under identical conditions from different polyvinyl acetates.

Comparison of the data given in Table 13 indicates that associated with the fall in viscosity of polyvinyl acetate occurs an increase in the flow factor of acetal increases, but its value, however, is still lower than the figure required.

Reduction of the quantity of catalyst to 1 per cent. also yielded no positive results. Nevertheless, it showed that the flow factor of acetal to a large extent depends on the degree of saponification of polyvinyl acetate. For this reason a number of additional experiments, so designed that the degree of saponifying could be partly reduced without hindering acetalysation, were carried out.

Study of the saponifying reaction reveals that addition of ethyl acetate to the reaction mixture should diminish the degree of saponification without impeding in any way the acetalysing process.

For the purpose of synthesis there was prepared a 48 per cent. solution of polyvinyl acetate in ethyl acetate with a viscosity of 3.28 centipoises, which figure roughly corresponds to the ratio of polyvinyl acetate to ethyl acetate as 1 : 1.

To the solution was next added alcohol and hydrochloric acid, the mixture being then heated up to the point of the release of the precipitate, after which paraldehyde was introduced. The liberated precipitate passed again into solution. The duration of the entire operation was 10 hours. Experimental results are summarized in Table 14. As may be observed, polyvinyl acetals derived by this method, by virtue of their properties of flow, water resistance, fusion temperature and hardness, testify to the possibility of their practical applications.

(To be continued)

REFERENCES

(373) *Ushakoff and Co-Workers; "J. Appl. Chem.," XII, C, 1939; ibid.*, 445, 1940. *"Plastics Monograph,"* 11,215, *Moscow*, 1937.
(374) *Austrian Patent No.* 145,525.

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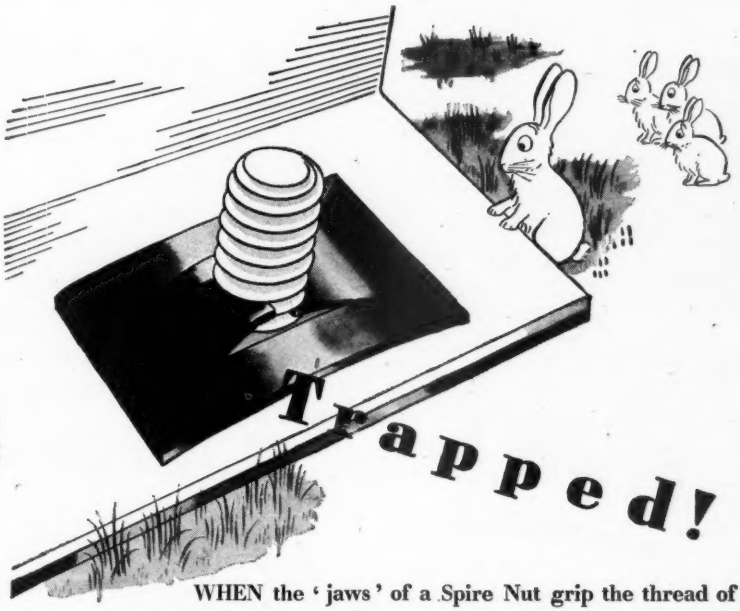

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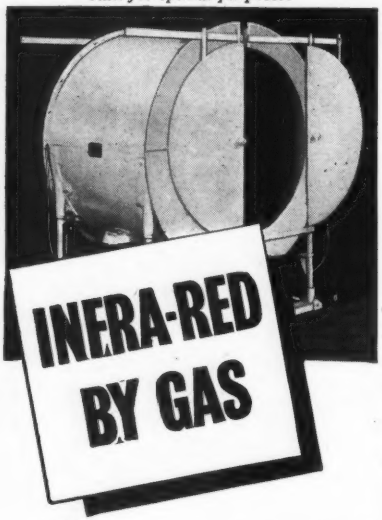

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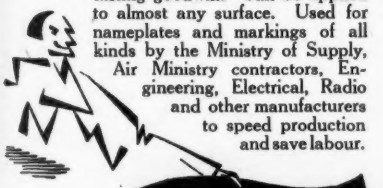

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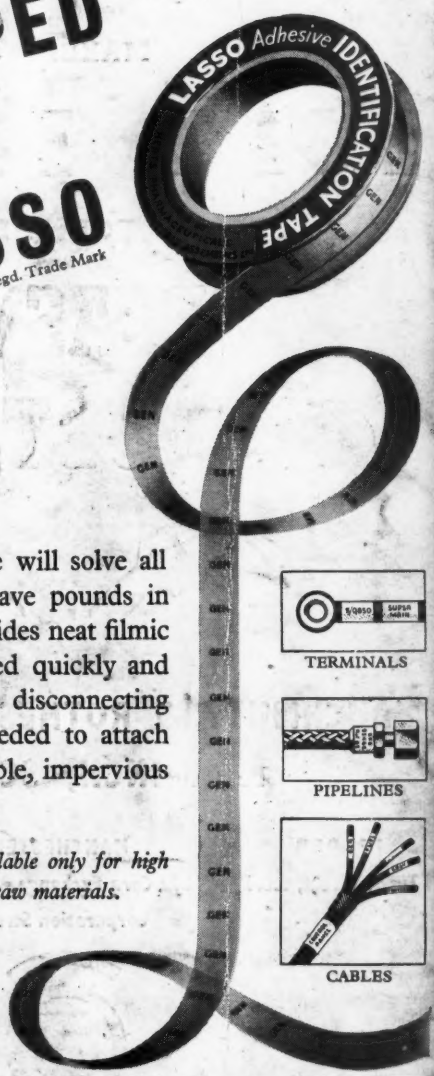

Lasso Identification Tape will solve all your marking problems and save pounds in time and labour. Lasso provides neat filmic markers which can be applied quickly and easily at any point without disconnecting the leads. No tools are needed to attach it, and it is durable and legible, impervious to heat and fluids.

Supplies of Lasso Tape are available only for high priority work owing to restrictions on raw materials.

TERMINALS

PIPELINES

CABLES

CABLE ASSEMBLIES LTD. (Subsidiary of Herts Pharmaceuticals Ltd.), BESSEMER ROAD, WELWYN GARDEN CITY.